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Frontispiece to D. J. F. Henkels History of Pyrites.



The Explanation after the Title

553.
THA 9A

PYRITOLOGIA:

OR, A
HISTORY
OF THE
PYRITE,
THE

Principal BODY in the MINERAL KINGDOM.

In which are considered its Names, Species, Beds, and Origin ; its Iron, Copper, unmetallic Earth, Sulphur, Arsenic, Silver, Gold, original Particles, Vitriol, and Use in smelting.

The whole compiled from a Collection of Samples ; from visiting Mines ; from an intercourse and Correspondence with Naturalists and Miners ; but chiefly from a Course of Chymical Enquiries.

With a PREFACE, containing an Account of the Advantages arising from Mine-works in general, and particular from those of Saxony.

Translated from the German of

J. F. HENCKEL,

Late chief Director of the Mines at Friberg in Saxony.

LONDON;

Printed for A. MILLAR, in the Strand;
And A. LINDE, in Catharine-Street, in the Strand.

M.DCC.LVII.

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H 513
E 1757
RB

An EXPLICATION of the FRONTIS- PIECE.

1. IS exhibited a sulphur hut, with the reverberating furnace and retorts, in which the sulphur is driven or forced out of the Pyrites.
2. In the vitriol hut is represented the leaden pan, in which the vitriol is boiled out of the Pyrites, together with a washing trough.
3. In the third hut, the desulphurated Pyrites is lixiviated, and prepared for making vitriol.
4. In the arsenic hut stands the reverberating furnace, with the dishes and subliming vessels out of which the arsenic is forced.
5. A coe or hut over the mouth of the shaft.
6. The mouth of a level.
7. A shaft, with the windlass, all having a relation to mining.

And as hot baths, vulcano's and whirlpools, derive their matter from Pyrites and sulphur, something about them is also exhibited.



ADVERTISEMENT.

R. Henckel's book on the Pyrites is in
the highest esteem with all lovers of mineralogy ; both, on account of the subject ; a leading body in the mineral kingdom, analysed into its constituent parts ; with the use and importance of these parts at the same time fully displayed : and on account of the method of treating it ; as a pattern worthy of copying after in our enquiries into nature, and a just specimen of the method of induction.

Nor is the whole less instructively interspersed with several fine and important observations in mineralogy, chymistry, assaying and smelting.

A translation, therefore, of so useful a book, it was hoped, would meet with a favourable reception from those who are lovers of a solid knowledge of nature, the genuine result of observation and experiment.

Dr. Henckel, however, though in other respects so excellent an author, is certainly but an indif-

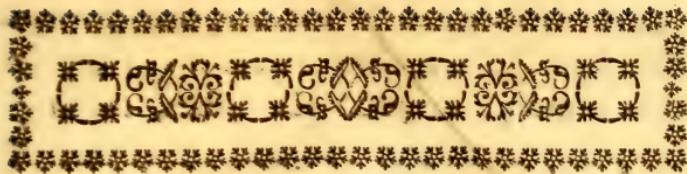
A D V E R T I S E M E N T.

ferent writer ; diffuse to a fault, and generally very obscure and perplex in his manner of writing ; with respect to which he has here been attempted to be abridged, cleared up, and unfolded : but his strain of low pleasantry and affectation of learning have been entirely dropt, as quite foreign, and consequently without any detriment to the subject.

Where the author, in the course of the work, has omitted to explain a term of art ; or, where any particular circumstance seemed to require a further illustration, a note has been added at the bottom of the page, in order to render the book as intelligible as possible.

With respect to this translation, much of the accuracy thereof is owing to a gentleman of uncommon eminence in this sort of knowledge, who was pleased to take upon him the revision of the sheets.

T H E



THE Author's PREFACE.

THE following particulars serving to shew the advantages accruing from the business of mining, both to the public, and to particular persons, may not be altogether unacceptable to the reader. As,

1. That the chronicles of Friberg and Misnia furnish us with extraordinary accounts of considerable *tenths* and profits, consequently of the great advantages arising from the Misnian mines, both to the prince and undertakers. In particular, that Henry the Illustrious, marckgrave of Misnia, had in the 13th century, from the mines of Friberg and Schneeberg alone, procured so many *tons of gold* * in silver, as enabled him to purchase the

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* A ton of gold is a method of reckoning money by; which in a country reckoning by dollars or florins, amounts to 100000 dollars or florins, &c.

viii The Author's P R E F A C E.

kingdom of Bohemia *. Further, that the weekly *tenths* from Friberg alone amounted in the fourteenth century, to 5000 rix-dollars, making in all a yearly income of 260,000 rix-dollars. The profits, therefore, to the adventurers, which amount to nine times as much, must have been 30 tons of gold †. And though ores may rise and fall in value, they notwithstanding yield a considerable income still.

From 1529, to 1630, a period of one hundred years, when the schedules were first published, the profits to the adventurers from Friberg alone, amounted to thirty seven tons of gold. At Schneeberg, from 1470 to 1510, a period of forty years, to forty tons of gold. At Anneberg, from 1496 to 1626, a term of one hundred and thirty years, to thirty seven tons of gold. At Marienberg, from 1520 to 1627, a space of one hundred and six years, to twenty four tons of gold. So that within the compass of one hundred years, taking one place with another, the total amount will come to several millions: and then it would be no difficult matter to make a calculus of the *tenths*, mintage, &c. falling to the share of the prince.

From an old written abstract it appears, that from 1590 to 1626, a space of thirty six years,

* Meissnische Berg-chronicke, p. 35.

† Freybergische chronicke, p. 431.

the *tenths*, the mintage, the duties from the huts, from the works of draining § and battery †, after deducting the profits for the adventurers, come to above twenty four *tons of gold*, and thus to a yearly income for the prince of almost a *ton of gold*. Whence we may easily see what the profits to the undertakers were. From 1603 to 1622, a period of nineteen years, the smelting huts of Friberg brought in to the electoral chamber above 100000 florins : the works of battery, and the duty on coals and wood in the territory of Schwartzenberg, from 1590 to 1620, a space of thirty years, above 150000 florins : the cobald and smalt works, from 1611 to 1623, above 100000 florins : the mintage of the burnt or fined silver of Friberg, from 1620 to 1623, and thus for three years only, above 80000 florins : the mintage at Anneberg, Marienberg and Schneeberg, after a deduction of the profits, for those three years, above 60000 florins.

And did we consider each groove and mine apart, many of them would be found to yield the like princely, nay royal income. To instance only

§ Draining at the huts, is the operation of separating the silver from the black copper, or the sort not quite freed of its sulphur, and other impurities. It is performed by smelting together a quantity of black copper and lead, and tapping them off into round cakes, which being set edgewise in a peculiar furnace, and exposed to a gentle fire, suffer the lead, carrying along with it the silver in the black copper, to drain or trickle from them, leaving the copper honey combed and spongy.

† The operation of beating out iron into bars and plates.

* The Author's P R E F A C E.

only in the sixteenth century : It appears by the Friberg chronicle *, there were above one hundred such works, which yielded quarterly, in profits to the adventurers, for one mine-action (according to the then division into thirty two shares) at the least ten ; most of them above thirty and forty ; many above fifty and one hundred ; nay, some, above two hundred ; and the Thurnhoff and Höhebircke in particular, above three hundred rix-dollars. And this we should well observe, as it shews, that not only one or two mines, are thus valuable, but generally all of them ; and obviates an objection, as if all these treasures were now quite exhausted : which is far from being the case ; our hopes being still as extensive, as there are grooves and mines to work, and field for receiving such a vast number of shafts and levels † : not to mention entire, unmeasured veins, which are so much fresh and unoccupied treasure.

Further, the accounts and instances we have of extraordinary rich ores in some works, should prevail with us to view the business of mining with other eyes than we commonly do. At Schneeberg in 1478, a rich silver vein was

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* P. 434. † Shafts are pits, sometimes perpendicular, sometimes oblique, sunk upon a vein. Levels are horizontal passages worked thro' a mountain, both for draining the mine of its water, landing the ore to the day, and for conveying in air. And for both these last uses shafts also serve.

discovered, and so large a wedge or block of ore, and native silver laid bare, that duke Albert of Saxony went in person down into the groove, and used this huge block, which smelted four hundred centners of silver, as a table to dine on *. And tho' such huge masses are uncommon, yet it is not unfrequent to see exposed at once, even within a narrow compass, large quantities of ore, as might, were a calculus made, come to several centners in silver. For not to mention masses of native silver, and of *glassy* and *red-goldish* ores, we find, at the proper depths, large veins of *lead-glitter*, or *galena* and the like ores. Nor is it at this day unusual at Schneeberg, Johan-Georgen-stadt, Ehren-friedersdorff, and the like noble mines, to discover whole nests of native silver, *glassy* and *red-goldish* ores, delivered into the smelting-huts by centners †.

2. That mines, as we have seen, constitute not the least, nay rather the principal branch of a prince's revenue, when once they are brought to bear, and have a proper demand on them ; the tenths alone making no inconsiderable part thereof.

3. That the advantages, indirectly or mediately, accruing to a state from mines are very great : in that they serve to support and increase the

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* Albinii Meissnische Berg-chronicke, p. 30.

† The mine-centner is reckoned at 110 lb.

number of inhabitants, afford the materials for trade and manufactures : and what we should principally here consider, the consumption of home and inland commodities, all yielding duties and taxes : by which means at least money comes to circulate longer in the country, and not fall into hands, that either hoard it up, or send it abroad for commodities, we may well be without. And it must be a standing proof of the value of mines to a country, when we read of whole cities and towns being built by their means : as it is to them alone, that Friberg, one of the most considerable in Saxony, owes its rise and present flourishing state, being, no earlier than the thirteenth century, but a poor despicable village, still constituting the most inconsiderable part of the town at present, and called the Saxon-town. Schneeberg, which comes next to Friberg ; nay, all the mine-towns in general, owe their rise to mines. And Johan-George-stadt, founded by the elector John-George, i. is a peculiar instance, that our country, even in latter times, is as capable as ever of having its mine-works improved, and brought to a flourishing state.

4. That the business of mining has, in our country at least, no small degree of preheminence above all others of what denomination soever. There is not a greater demand for any one thing than for the produce of mines ; and yet nothing is rarer in any country. No country is without manufac-

nufactories ; but many, without mines ; most without serviceable ores ; many, especially on the score of situation, scarcity of wood and water, unfit for carrying on the business of mining. In a word, mines are, as it were, a privilege peculiarly bestowed on some countries, exclusive of others, and therefore to be highly esteemed. But to conclude, what are all the subjects of the grand manufactures in Misnia other than those supplied us by mines ? For instance, the famous small-work at Schneeberg, which has yielded so many millions both to the prince and adventurers, is nowhere in the world to be matched, and consequently to be deemed a peculiar treasure. Our salt-springs too are a kind of mines. Tin is a metal become very necessary in common life, and yet, in some measure, the rarest of all others. There are but few tin-mines in Germany ; nay, in respect of other metals, few in Europe. All in Germany, as far as I know, are those in Misnia, Bohemia, and Carinthia, and formerly in the Fichtelberg at Wonsiedel. Whole kingdoms, as Sweden, Denmark, Norway, &c. have no such mines, but are obliged to be supplied with tin from England : and all Germany, from Misnia, Bohemia, and England too.

5. That our Misnian mines in particular have by far the preference to all others in Germany. Two things, namely *levels* and wood, are indispensably

Pensibly necessary for carrying on a mine-work. The former, in order duly to reach home to the proper depth, and through such subterraneous canals to drain off the water into a valley; in order thus to supersede the use of expensive engines. The latter, in order not only to timber and secure, where needful, the *shafts* and *drifts* *, but also smelt and work the ores for their metal. Now, as to *levels*, our forefathers have, for instance at Friburg, left us such extraordinary works in this kind, as that, in want of them, our mines would become quite impracticable; particularly that called the *prince's level*, one of the grandest works in these parts, considering the time, labour and expence necessary to work a passage under ground through firm rock, for about five English miles in length. As to *wood*, the want of that in particular disqualifies many places for mining. The expences at the *day* in aqueducts, trenches, stamping and wash works, in engines, in constructing the smelting and other huts, in wooden trunks, good *additions* † or fluxes, serviceable *flags* or *scoriæ*, &c. Things absolutely necessary in the busines of smelting, come very high in some places, but not so in Misnia. Nor must I omit mentioning to our honour, that both

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* Drifts are horizontal passages, much in the nature of levels designed either for going upon a vein, and digging out the ore; for conveying off the water, or for conveying the ore to its place of collection, or the bottom of the shaft.

† By additions smelters mean those matters added to their ores, in order to procure their yield, or to work them to better advantage.

for the business of mining and that of smelting, we have the ablest, most experienced and ingenious artists in the whole world : nor this other considerable advantage, peculiarly our own ; namely, the variety of our ores, than which nothing is more serviceable in the business of smelting : as by properly dosing and mixing these together, we are able to work to better advantage what would otherwise remain unsmelted, and be forced off among the *slags*. And who could ever have imagined, that *red-goldish*, and the like rich ores, should fail to smelt, if not worked with *pyrites*? And yet this is what for some years past our neighbours at Nicolas-mine in Bohemia have sufficiently experienced : whence they are obliged, at much expence and labour, to be supplied with the *pyrites* from us ; in order previously to *crude-work* their poor, *quartz*y ores : that is, smelt them crude along with desulphurated *pyrites*.

My view in all this is to shew of what consequence the knowledge of ores, or the business of mineralogy is as a foundation for those of mining and smelting : and that a very serviceable, important subject is the matter of my present enquiry.

verso il centro dell'isola del
Caribbeano.

Il suo percorso è stato sempre e
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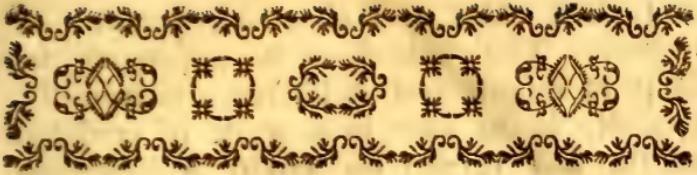
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Alfredo P. de la Torre, che ha



P Y R I T O L O G I A: OR, A H I S T O R Y O F T H E P Y R I T E S.

C H A P. I.

The Subject propounded, with the Manner
of treating it, &c.

T length appears this promised history of the *pyrites*. And considering
A the length of time I have been em-
ployed in it, many of my readers
might, perhaps, expect a larger work
on the subject, and to have had it sooner. To
such I offer the following reasons by way of
apology.

I. A multiplicity of avocations: my station
and circumstances in life being such, that many
times for half a year together I have not been
able to bestow so much as a single hour upon

2 *The SUBJECT PROPOUNDED.*

the subject, either as a chemical operator, or as a writer. Tho' indeed, to be ingenuous, something of disgust and indifference interposed; as generally is the case in a work of considerable length, and carried on amidst a dissipation of thought. Nevertheless, such as it is, I have spent so much time and been at so great expence in this performance, that I know not whether, under the same circumstances, I should ever again be able to execute such another.

2. The importance of the subject: more than a little time was required to procure from the several countries and mines their several species or samples; and the English samples, dispatched for me by the celebrated Dr. Woodward, never came to hand. A repetition of some experiments was also necessary, especially to determine the very slow vitriolisation of several sorts of *pyrites*, further to confirm my opinion of this mineral body, and to procure the remarks and sentiments of my correspondents concerning it.

3. My method of treating the subject: it was not my intention to fill up my book with transcripts from authors. Nor indeed had I ever so great a mind to it, could I well; seeing nothing useful to my purpose could be found in them.

But is it readily to be imagined, that the treating a subject in the laboratory, and the discovering a new truth, shall require no more time than the writing over a few leaves of paper? I may truly aver, there is many a truth and many a very short proposition, which I was obliged to retain in my thoughts, through the course of this enquiry, as it were in labour, to bring them to the birth, here set down in the compass of a few lines, that employed me not only days and Weeks, but even months to ascertain. And yet, after all, some others remain behind,

on

on which I might have spent a great many years; or even my whole life, and not be able at last to place them in a clear light, and free from every objection.

One of my views in this undertaking was to set a pattern to others, who may happen to have better helps, than I can well challenge, to prosecute this subject to a greater length. Another, to engage the attention of mankind in the study of nature: a solid and useful knowledge of which is rather to be hoped for in this manner, than from the books commonly wrote on the subject. But from this track we are generally diverted, either by our present method of education, consisting for the most part in learning the application of lines and angles, as the nearest step towards the attainment of the knowledge of bodies, whereby we entirely disregard the study of nature in herself; that is, in the forms, mixtures, and qualities of bodies; tho' by far the most important and useful. Or, thro' a remarkable degree of indolence, notwithstanding the pleasure attending the pursuit, chuse to forego the trouble, generally accompanying the making proper experiments and observations; especially processes by fire, where every circumstance is to be registered, or set down with the greatest care, and accompanied with proper remarks. Nay, where a single over-sight, the springing of a glass, or even a groundless scruple, after the proof or trial is over, may occasion the repetition of an experiment, perhaps, several times. Tho' this very trouble is abundantly compensated, by the solid knowledge and experience we derive from thence to ourselves: hereby we have a lively and clear conception of things, in cases where books prove useless, nay fallacious; and are enabled to pronounce with boldness and certainty concerning

ing the truth or falsehood of any proposition. Nay, even the very noting down the several circumstances of a process must be advantageous, by affording a constant directory for repeating the experiments afterwards, without any fear of a miscarriage: and the comparing one truth or axiom with another, cannot fail to yield us just and solid conclusions, as well as the best materials for laying the foundation of a solid natural knowledge.

A principal motive to the present undertaking, in which I could wish to be imitated, is the improvement of natural history. A person, conversant with things, and not with books only, must needs experience the insufficiency of our present philosophy, and how few subjects are treated by writers with accuracy and precision enough, to give full satisfaction to an inquisitive mind. Instances of their negligence, in this respect, are every where obvious; but no where more so, than on the subject of the *pyrites*; no one author having hitherto supplied us with any clear description, or tolerably accurate distinction of this important and leading mineral body. I say not this merely with a view to find fault, being rather inclined to commend the care and diligence of those, who have gone before me: nor do I presume to set up my own performance for faultless and finished; but to expose the indolent methods of those writers of our days, who content themselves with being mere transcribers. In our enquiries after truth, we ought to use a freedom and openness in animadverting upon the imperfection of our knowledge: Nor should we stop short with the ancients; but taking up one body after another, consider each with due attention and leisure, and thus collect materials for latest posterity to work upon, and therewith

with raise better systems than we are at present pos-
sessed of.

Of what consequence chemical enquiries into nature may be, will appear from some discoveries I have accidentally made, in my examination of the *pyrites*; from which, and a certain kind of earth, each separately barren of silver, I procured an actual silver: also from *pyrites* itself, a steel tincture peculiarly sweet, and without that roughness, common to such tinctures; also from my enquiries into the nature of the *pyrites*, I have gained no small degree of knowledge in the business of smelting ores.

As to my method of procedure in the present enquiry; I have, in the first place, laid it down for a rule to myself, to abide strictly by matters of fact, without giving into any hypothesis or empty speculation whatever; and, therefore, I attempt not to separate or resolve the *pyrites*, either into the four elements, the three, or other imaginary principles; as being things that can never be made objects of our senses; or that any one can so explain, as to convince an impartial enquirer, that these are the essential constituent parts of our subject: a rule as indispensibly necessary, as it is generally but little regarded. 2. I have put the *pyrites* to several accidental proofs, and by that means often discovered, what I otherwise could never have hoped for. That from the acid vitriolic-salt, and the alkaline earth of the herb Kali or Soda, a blue colour should be procurable, is what no one could beforehand suspect: as little, as that the *pyrites* should yield a sweet iron-tincture; or, that a species of earth, in itself destitute of silver, should, by means of the *pyrites*, become remarkably silvery. 3. I never scrupled several times to repeat a single experiment; either up-

on the breaking of a vessel, or other failure in the course of the process. 4. I have used the greatest care in chusing and separating the several matters employed ; a circumstance of no small importance ; for, not to mention the various sorts of solvents, salts, &c. (which notwithstanding are to be well examined in respect to their goodness ; so as we may be able to distinguish, for instance, between alcali and alcali, salt of tartar and potash) we must be careful, knowingly not to employ for proof any communicative *additions*, but the bare *pyrites* alone. The several samples employed, were such as I either originally procured myself, or had from persons of credit and veracity. These I carefully examined and separated from each foreign admixture : which was found needful, even when externally they seemed to give no such suspicion ; as is plain from the *steely* or close *pyrites* of Pretzendorff ; having experienced the seemingly purest sort of them, to be not only internally full of fissures, or fibres, but these fissures to be often mock-lead, and thus apt to misguide or at least to puzzle the most careful operator. And the *pyrites-kidneys* of Franckenberg, how close soever they may seem externally, and how similar soever, internally, yet shew not only a black mock-lead impurity, but also such interspersed pieces of *copper-pyrites*, as are evidently distinguishable from the rest of the sample, namely, the genuine *iron-pyrites*. 5. A no less degree of care I used with regard to the vessels and instruments, employed in making the experiments : a caution of greater importance than the unexperienced may imagine. The colours manifesting themselves in experiments, shew much of the internal nature of bodies, and their productions : or, at least, how one sort comes to differ from another ; and are of so peculiar a nature,

as

as that a single drop of a foreign liquor, or the least grain of a salt, or smut, shall change them : and therefore, to procure such as are beautiful, the greatest nicety and care are to be used, as in this case, having to deal with one of the most delicate subjects in nature. Nay, mixtures themselves come out very different, without the greatest care be had to make perfectly clean a vessel once used, or to employ a new one ; a little common salt, or sal ammoniac, directly adulterating aqua fortis ; the least quantity of a contrary salt marring an intended fermentation ; and a lixivious salt, which has conceived only a little acid from the air, becoming unfit for the mercurification of metals, as well as for other processes. And in the business of assaying, there may something, which may serve to falsify a proof, stick to the ore-dish, or to the hammer, wherewith the proofs are rubbed, or even to the hare's foot. And in the desulphuration of the *pyrites*, we might, without using new retorts, nay, even new receivers, easily be imposed upon, or at least, not so certainly observe what *pyrites* are, and are not, arsenical : as the arsenical impurity may unobservedly lodge in retorts and receivers, not sufficiently cleared thereof ; nor will the fetid arsenical smell, very soon wear off ; whence also the weight of what passed over, and what remained behind, cannot always be taken with a necessary exactness ; a circumstance, to be well observed. 6. Another direction of moment, is the accurately entering the several experiments into a particular journal ; the numbering the several glasses, boxes and cases, for holding the different matters to be worked, and the several productions procured ; either for a farther examination, or future use.

And though the *pyrites* be a mineral so very common, that there is scarce any earth, stone,

fibre or vein without it, and of such extensive usefulness, supplying us with sulphur, arsenic and vitriol, those capital instruments both in nature and chemistry, and with one of the most powerful fluxes (especially with us in Germany) for forcing stubborn ores to give forth their contents ; yet its nature is hitherto so little understood, and all the accounts we have of it are so very lame, no one having either clearly described, or accurately distinguished it, that an attempt to put it in its proper light should seem to want no apology.

But to give the reader a still nearer view of my manner of managing this subject : I have examined upwards of 60 different samples of *pyrites*, procured from different parts ; considered each sample apart in its colour, texture, and specific gravity ; exposed a little of each to the air, in order to discover which sort would, and which would not, be affected and opened by it ; to the fire, for its contents ; to the action of the magnet for its iron, both in the crude and calcined state of the sample ; to aqua fortis and aqua regia, for the gold and silver ; nay, to vinegar and spirit of sal ammoniac, for discovering the copper in it : some samples I have boiled with alcaline lixiviums, with lixiviums of common salt and allum ; the one to separate the sulphur from its metallic earth, and form a *hepar sulphuris* ; the other, for the vitriol acid to lay hold on the alcaline earth, and discharge the acid of the common salt ; consequently to exhibit an Epsom, or the like salt of a mineral water, or a Glauber salt ; and thus to serve to establish my conjectures on the original of *acidulæ*. I have combined the several parts of the *pyrites* with each other, and with other bodies ; nay, the entire *pyrites* itself. I have examined the *capita mortua* of the *pyrites*, in the same manner as the *pyrites* itself : in particular, I have mixed

the *pyrites*; sometimes with sal ammoniac, whereby I have procured the saffron iron-flowers; sometimes I examined it by detonation with salt-petre, in order to find out the different proportions of its inflammable earth: and lastly, took a great deal of pains in assaying it, by employing, as *additions*, various sorts of earths and stones.

Volcanos and *Thermæ*, are, in a great measure, owing to the effects produced by the *pyrites* in the bowels of the earth. As it is well known that iron and sulphur perfectly, and with ease, take fire along with water. By means of these it was, that the elder Lemery attempted, in the small way of experiment, to imitate the effects of volcanos and earthquakes. And for this purpose he ground iron and sulphur, which, with water, he made into a paste; which, after standing for two or three hours in the open air, began, without any application of fire, to grow remarkably warm, then hot, at length to heave and ferment; and thus the mass, in several places up and down its surface, came to have several cracks and rents, thro' which there transpired a fume, which proves only warm in smaller, but actually takes fire in larger masses, as of thirty or forty pounds. From this experiment he attempted to account for the burnings of *Vesuvius*, *Aetna*, &c. And with that view he proceeded as follows. "I put, says he, "some of this mixture of iron and sulphur, both in "to larger and smaller, and into taller, narrower "pots; and the matters, as lying there more "close and confined than in earthen dishes, be "came more violently heated and heaving, and "in part sprung out of the pot. Further, in "summer-weather I filled a large pot with fifty "pounds of this matter, and covering the pot "with a linnen-cloth, buried it about a foot deep
"in

30 The SUBJECT PROPOUNDED.

" in a hole in the earth, and covered all with
" earth. In about eight or nine hours after, the
" earth beginning to heave, heat and spring up,
" there burst out a sulphureous hot fume and an
" actual flame, which enlarged the rents, and a
" yellow black powder settled superficially round
" about them. The earth remained a long time
" warm : and when I came, after this, to dig
" out the pot, I found remaining only a black heavy
" powder, &c. This process succeeds better in
" summer than winter, as the sun's heat may
" be supposed to have a better effect on the sul-
" phur and iron." He then proceeds to ob-
viate some objections. As, 1. Whence volca-
nos come to have their air, without which there
can never happen any accension. 2. How a-
midst much moisture, as the water of the clouds,
the matter of thunder and lightning, should come
to take fire: as to the first, 'tis easy, says he, to
conceive that the earth, a porous, permeable bo-
dy, is equally filled, as it is invironed, with air.
The second he endeavours to explain by means of
that experiment, where, in making iron-vitriol
with the acid of vitriol and common water, the
fumes arising from the glass body take fire, and
burst out into actual flame, by approaching a
candle to them, as though they were spirit of
wine, notwithstanding these inflammable sulphur-
particles are envelop'd in water *.

Lastly, As to *Thermae*, or hot springs, I ima-
gine no one, acquainted but superficially with
their internal constitution and nature, will call in
question their partial origination from the yellow-
ish or sulphur-iron pyrites; I say *partial*, and not
total origination; in regard that these, in parti-
cular the *acidulæ*, as the *Caroline*, &c. carry along
with

* Mem. de l'Acad. Roy. l'ann. 1700, p. 131. Seqq.

with them some highly predominant and capital matters, namely, a lixivious salt, and a calcareous earth, which cannot be supposed to be derived from any one sort of *pyrites*; but probably, if not from common salt, from lime-stone; and if not from this last, from spad, which is a calcareous sort of stone; and if not from spad, from so fatty an earth and stone, as that from which the aluminous lime-earth is generated. For, who is not convinced that these springs generally contain something vitriolic, which remaining untouched by the lixivious salt, exhibits a formal vitriol; or, in other words, its acid salt may be made to separate from the alcali; and thus form a bitter spring-salt, its metallic earth falling as an ochre to the bottom. And sulphur itself formally effloresces about such mineral springs, as those of *Aix-la-Chapelle* in particular. Now sulphur, the vitriolic acid, and a metallic ochre, are parts derived from *pyrites*, and not from stone-coal or bitumen.



C H A P. II.

Of the NAMES* of the PYRITES.

IN natural history, and more especially in the fossile kingdom, fancy rather than judgement appears to have determined the names of a great variety of bodies: thus to imaginary or accidental circumstances the *Dendritis*, *Selenites*, *Myrrhinites*, *Ætites*, *Astroites*, *Bufonites*, with many more, owe their respective denomination. With respect to the mineral under consideration, its name, *pyrites*, or fire-stone, has, above most other fossils, the good fortune to be equally just and expressive.

It is called a stone in the same sense, as all ores, that are not quite spungy and friable, are so denominated from their hardness, weight, and closeness; for instance, *lapis aeris*, *lapis ferri*, copper-stone, iron-stone, &c. however, we are not to confound it with the *horn-stone* [flint] which is used for fire-arms, and at this day commonly called by the Germans *fire-stone*.

Pyrites more especially derives its name from fire, as it contains a larger share of sulphur, which is the *pabulum* of fire, than most bodies in the mineral kingdom: not indeed more than all ores, seeing cinnabar and antimony ores, also stone-coal, partake considerably of sulphur; nevertheless, it claims a preference in this respect to all ores of a stoney nature, which the three abovementioned cannot be properly deemed, on account of their friability, and extreme loose texture. In

* It is but justice to the author to take notice that, under this head, he has shewn great assiduity, and displayed more than a common share of learning, in tracing the Etymologies of the several names applied to *Pyrīta*. These, however curious, are apprehended not the most useful parts of this work; for which reason the translator acknowledges that he has taken greater liberties in his abridgement of this chapter, than in any other.

In High-Dutch *pyrites* is called *kies*; whence this term is derived is not very easy to determine; perhaps the first inventor of it had in view the *kiezel*, or flint-stone, as *kies* and *kiezel* are so far analogous in that both strike fire: or it may well enough be derived from *erkiesen*, to chuse, as that stone or rock is, in mining, to be *chosen* before all others, where such a sulphureous vitriolic iron and copper ore offers, seeing the *kies* can lead the miners, as by a clue, to the wished-for labyrinth of gold and silver veins: also, when two undertakers have branches of veins running together, and afterwards separating, and coming out of the compass of the share, the elder must *chuse*, or pitch upon a branch, which he cannot readily do without *kies* †. But should neither of these derivations be approved, it yet may be allowed to pass for a venerable old German mine-term, till its genuine etymology can be ascertained. It is at least so common a word among Germans, that I know of no province, in which the language is spoke with propriety, where it is not in use; only with this difference, that some are not accustomed to apply it to such *pyritæ* as are very coppery, or highly arsenical: for instance, at Friberg, the former are called copper-ore, the latter *misspickel*; with these the term *kies* is wholly dropt; while others, particularly at the Hartz, are wont to call even the richest copper-ore *kies*, as, *copper-kies*.

The Arabians use to this purpose the term *marcasita*, marcasite, which the Germans also have, from the Romans, in some measure, adopted. This appellative, though, strictly speaking, it is not, under certain circumstances, improperly applied to the subject here treated of, has been made use of, by different authors, to denote such a vast variety of mineral substances, as well artificial as natural,

† Rosler's Berg-bau Spiegel [Mine Mirror] i. 4. c. 4. § 14.

natural, that it ought not to be received but with some caution, and under many restrictions. The druggists seem to understand by it *bismuth*; and the alchymists, who indeed generally affect confusion and obscurity, have made it to express not only *bismuth*, but also *regulus of antimony*, *spelter*, and most of the known semi-metals. Among the mine-men, particularly those of Misnia, by *marcasite*, according to the best information I could get, is meant our *pyrites*, or *kies*; not generally, but only when finely angular, smooth, and especially of a cubical form, and of a gold-glittering cast. On the contrary, another, though broke off from this very piece, which in the fresh break has the very same colour, and which affords the same contents, if it happens only to differ in the external figure, is not, on any account, allowed the name of *marcasite*.

Under the like circumstances of confusion and ambiguity, the term *Magnesia* has been introduced into the history of the *pyrites*; particularly by alchymical writers, as Flamellus *, who gives this denomination to the *pyrites Achaea*; and Bohnius † uses the same expression (with the addition of *Vitriolata*, on account of its easy resolution in the air) to denote the Hessian iron-earth, which is a real, and indeed a first-rate *kies*. However, among mine-people, and in common language, the term is very little, if at all known, except with the glass-makers, who mean by it a martial mineral, more commonly called brown-stone, of a dusky colour, rather inclining to black, and spicular, like antimony. Its use in the glass-houses is to give a due whiteness and transparency to the better sort of glass: the potters also employ it in glazing their manufactures. In Italy it is known by the name of *Manganese*. But though the word *Magnesia* is

not

* Theatr. Chym. T. IV. p. 863.

† Bohnii Dissert. Chym. IV. p. 108.

not generally made use of, and has often been injudiciously applied, to signify *pyrites*, if it be considered, that many species of *pyritæ* powerfully attract the air, which is the most natural sort of vitriolisation, this appellation, derived from their *magnetical* quality, will not appear altogether unjust, or improper.

Bernh. Cæsius §, and Festus Pompeius, seem to have been deceived by appearances, and to have meant a *pyrites*, by what they have called an *Aurichalcum fossile*, or a native fossile brass. Ulysses Aldrovandus has clearly discovered the mistake of the latter; a mistake, that nothing but a profound ignorance in mineralogy could have occasioned.

Igniarius, *lapis luminis*, fire-stone, light-stone, are names more justly appropriated to *kies*, or *pyrites*; seeing by a smart sudden stroke against steel, they emit sparks of fire and light, that manifest themselves by the accension of gunpowder, tinder, or such matters. However, *pyritæ* differ in this respect, according to their contents; those that partake most of copper, afford the fewest sparks, and by how much more they are impregnated with iron and sulphur, the most; though even the white arsenical *pyrites*, or *misspickel*, that yields no sulphur, will exhibit some fire.

From hence the Germans have given to *pyrites* the name of *Buchen-stein*, fire-lock-stone, as it was formerly used for fire-locks: but in order more effectually to answer this purpose, care should be taken to chuse such as are the hardest, most dense, and capable of being worked into a proper form.

Mart-

§ L. I. c. 9. p. 130.

¶ Quando Festus Pompeius scripsit *aurichalcum* in montibus nasci, proculdubio non est locutus de aurichalco, arte parato, quod ex ære et cadmia conficitur, sed fortassis hunc *Pyritem* intellexit, qui aurichalcum perbelle æmulatur. Aldrov. Mus. L. VI. c. 3. p. 514.

Mart-stein is another denomination of *pyrites*, and far from being attended with any impropriety; as its etymology may be deduced from *Mars*, or iron, and this fossile is principally an actual iron-stone.

Vulcan, the god of fire, being under great obligations to the *pyrites* for his best fuel, as appears from those huge laboratories in mounts Hecla, Ætna, and Vesuvius, the subject of our present enquiry has been honoured with the title of *Hephæsticus*, or *Hypetionus*.

As iron makes a principal part in the composition of the *pyrites*, *sideritis*, σιδηρίτης, iron-stone is no inadequate appellation; nor, if its igneous qualities are duly attended to, can *pyropus*, *pyrobolus*, *pyrimachus*, terms used by some of the antients to signify the same thing, be thought very improper.

Othonna, according to Gesner, is a copper-coloured ore in Egypt, which Aldrovandus takes to be the same with *lapis luminis*, and Aristotle's *pyrimachus*:—*Atrament-stein*, or vitriol-stone, has also been numbered among the denominations of *pyrites*; but of this last appellation more hereafter.

Corallus, coral-stone seems to be misapplied, when appropriated to *pyrites*, seeing though the rock wherein it lies is often found red, the genuine *pyrites* never exhibits that colour.

Chalco-pyrites is an useful distinction of the coppery sort: nor is the *affius lapis*, or as Agricola expresses it, *Asiae lapis sive lapis ex Asia, ubi nascitur sarcophagus*; that is, where the flesh-consuming stone grows, altogether improper, as the corrosive power of vitriol is well known.

But it is high time to have done with mere names; let us proceed to what it is hoped will afford more real instruction, which, to the utmost of my ability, is intended in the succeeding chapters.



C H A P. III.

Of the several SPECIES of the PYRITES.

PYRITES, or *kies*, in the sense we are to take it, is a mineral or ore, partly white-grey, partly yellowish grey, partly brass-yellow; having for its constituent principles a metallic, namely, an iron earth, which is its proper characteristic; a volatile matter, as either sulphur or arsenic, or both, tho' the former prevails more frequently; some sorts are found to partake largely of copper, with which is generally found a mixture of silver, but in a very small quantity, and sometimes an appearance of gold, tho' this is rather imaginary. The *pyritæ* are commonly worked for sulphur, arsenic, sandarach and vitriol, the last of which ought not to be looked upon as an original principle, but as a production consequent of the combination of the other principles.

The parts of the *pyrites* may also be considered as they are either essential or incidental. With respect to the former, there is properly in nature no more than one sort of *pyrites*; for in all there is iron, and this iron is the primary constituent part; every *pyrites* being an iron earth, either sulphurated, or arsenicated, or participating of both at the same time. In an incidental view, *pyrites* are distinguished, 1. with regard to their metallic contents. 2. Their sulphur and arsenic. The former may be divided into iron and copper *pyrites*, the denomination being here taken from what constitutes the greatest part of this composition. At Friberg, the copper-*pyrites* denote such as yield

one, two, or the like small number of pounds of copper, and called at Friberg *copper-ore*. Thus were *copper-pyritæ* distinguished by a peculiar name, whilst the *iron-pyritæ* lay neglected, under the simple denomination of *pyrites*, or *stone-pyrites*, or *sulphur-pyrites*, without any distinct appellation that should denote the essence of it. At Friberg all such are *iron pyritæ* as hold little or no copper.

That kind called *gold pyrites*, when accurately examined, as I have done all of them, proves either a highly coppery sort, or the common *pyrites*, shewing externally of a beautiful gold-colour; these are particularly procured from Hungary, and have groundlessly raised extraordinary expectations. Tho' when any gold or silver is procured from *pyrites*, it may happen either from the spangles or threads of these metals, or from a genuine silver-ore being unobservedly intermixed with the sample under proof. Again, Men have been apt to be imposed upon by the gold colour cast of the sample, whence the ancients called it *pyrites aurei coloris*. After all, the gold generally procurable by such proofs is very inconsiderable; nay, what is to be met with in almost all mineral glebes, and in most, if not all silver, for procuring which no *pyrites* was ever particularly employed.

Much the same we may say of what is called *silver-pyrites*; the same cautions are necessary to prevent being deceived by the colour; in regard the *misspickel* or *arsenic-pyrites*, that is, the white *pyrites*, by the ancients called *pyrites argentei coloris*, comes properly under that distinction, tho' usually holding the least silver, in comparison of the yellowish and yellow: and tho' almost all *pyrites* hold some silver, yet it may be queried, whether it does so as a *pyrites*, without the intermixture of any other foreign vein. The mine-

secre-

secretary, Mr. Lichtwer, a person extremely well skilled in the business of minerals, shewed me sometime ago at Dresden a steely-close *pyrites-die* from Norway, from which there issued a pretty large thread of native silver: But this silver we must not consider as growing out of the body of the *pyrites*, but as something existing previous to, and encompassed by the *pyrites*, and which probably might have had its root or origin in a *quartz* or *spad*, as such a body actually adhered to it, and in such, native silver often lodges; having myself had from Norway a *quartz* or flinty sample, closely intermixed with foils of silver, under the title of a *silver-pyrites*, tho' nothing of a *pyrites* was observable thereon.

From the other contents of the *pyrites* have arisen the appellations of *sulphur*, *vitriol*, *arsenic* and *sandarach pyrites*, and accordingly *pyritæ* have in some measure been sorted; in particular, sulphur and vitriol *pyrites* is a distinction without a foundation; seeing all *pyritæ*, containing sulphur, yield vitriol too; and all yielding vitriol, must needs have held sulphur: but it is proper to observe, that they must be first worked for their sulphur, then for their vitriol; and that *pyrites* once worked for vitriol, irretrievably loses its sulphur. So that this division of *pyrites* has only served to introduce error and misconception into the subject; as if these were quite distinct species of *pyrites*, and that some *pyrites* held vitriol formally, and in their native composition, in manner as most of them do sulphur. Tho' this is not to be taken strictly neither, as there are some attending circumstances to justify such a division, for the sake of illustration, tho' not of necessity: for instance, at Geyer in Meisnia there are chiefly two sorts of *pyrites*; the one of *Catherin-mine* at Johanna-Georgen-Stadt; the other, of the *pyrites-groove* of

Geyer itself: from both which sulphur may be driven or procured; yet it is actually worked from the first sort only; as the other, on account of its greater impurity, and consequently large *heap-work*, and the tediousness of working it, would not compensate the trouble. On the contrary, there is vitriol procured from both sorts: from the first, as the sulphur and vitriol are almost at once worked for, or the advantages of working the sulphur exceed the vitriol expences: from the second sort, as the expences of desulphuration, wherein the proper furnaces, and vessels, and attendance come high, are superseded, and the ore only prepared by a course of common *roasting*. Now as that sort from the *pyrites-groove*, on account of its foreign admixture, which is chiefly an iron-stone, is not worked for sulphur, it may with some propriety be called a vitriol, and not a sulphur *pyrites*, and may in some measure be opposed to the other: might not therefore the persons, who first applied these names, have a regard to the spontaneous vitriolisation of that sort, and imagine them to have vitriol only, and no sulphur? Now, from my own small experience in those matters, I look upon all *pyritæ* containing sulphur, spontaneously to resolve to a vitriol, tho' many slowly and with difficulty; the fewest, with dispatch and ease. Yet it might be allowed, to call those that instantaneously vitriolise in their entire substance, without any refuse, out of eminence *vitriol-pyrites*; as the Hessian *iron-earth*, for instance, called also *Magnesia vitriolata*; and in general, the *pyrites* consisting of iron and sulphur, without any other admixture, and of a round figure.

The division into sulphur and arsenic *pyritæ* is better grounded. Of the first sort are all those at the mines and smelting-huts, called simply *pyrites*, and employed for procuring that regulus, called *crude-stone*, sulphur, &c. Again, all copper-*pyrites*

pyrites and copper-ores, which tho' with us not work'd for, yet contain sulphur. Tho' *arsenic-pyrites*, in its metallic contents, especially iron, coincides with the other, yet in its volatile part it differs greatly. And tho' sulphur and arsenic are often found together in *pyrites*, yet there are some without any arsenic at all; and again, not a few that contain no sulphur, but only a pure arsenic. Further, tho' sulphur and arsenic readily unite, yet are they never produced the one from the other. So that this division, in preference to the others, particularly the foregoing, may be permitted as taken not so much from the different matters for which this sort is worked, as from their different principles, and seems to have some foundation in nature. At Friberg tho' we use not the term *arsenic-pyrites*, yet we denote the same thing by *misspickel* or *white-pyrites*. 'Tis here to be observed, that the black *arsenic-pyrites* or *fly-stone*, is not properly of this class, as being entirely fugitive, without leaving any fixed earth behind, and consequently having one part only of the essence, and not the other fixed, metallic principle of a *pyrites*.

The appellation *sandarach-pyrites*, has introduced numerous mistakes: sandarach is only a sulphurated arsenic, or an arsenic tinged yellow with sulphur, not having its own peculiar *pyrites*, contradistinguished from the *arsenic-pyrites*, as one might be led to imagine: seeing it consists of the very same parts peculiar to the *pyrites* itself; only that these are seldom lodged together in a due proportion, to fit them to be worked for sandarach, without making some additions. In most *sulphur-pyrites* there is at last procured a small quantity of sandarach (as most of them hold some arsenic) and but a little; and that either in the course of purifying the crude sulphur, as is observable from the beautiful transparent, ruby-red sublimate, and

orange-coloured powder, or from the residue or *sulphur-slags*, as they are called, with or without further treatment; or also in the roasting-huts, which generally appear done over with a red sort of glazing. Some *pyritæ* yield more of it, but still in the proportion to their sulphur and arsenic. Tho' to speak with propriety, it would be a difficult matter to find a *pyrites*, so mixed by nature, as without large additions to yield much sandarach, and not either mostly a sulphur, or a pure footy arsenic; for, to compose a sandarach, the arsenic must predominate or exceed the sulphur by about 3 or 4 parts; and a *pyrites* of such a mixtion is very rare, and what I never myself observed; but rather, that where the *pyrites* greatly partakes of arsenic, the sulphur is deficient; and where, on the contrary, the sulphur is in a sufficient, not to say, a large quantity, there the arsenic is not so. The *misspickel*, or *white pyrites*, is therefore for the most part purposely mixed, either with sulphur-slags or with *sulphur pyrites*, as shall be shewn hereafter. 'Tis true, the *white-pyrites* might be, nay, by some is really called a *sandarach-pyrites*, and 'tis possible there may be *pyritæ* having such a proportion of sulphur and arsenic, as to yield sandarach without using any additions.

But the usual way of procuring a sandarach is to employ two sorts of *pyrites*, the white and the yellow, or to use, as additions, *sulphur-slags*; whence it appears, that sandarach is not a constituent principle of *pyrites*, but that it consists of two parts thereof, namely, arsenic and some sulphur, really, but dispersedly, existing in the *pyrites*, and run together in the course of the process for sandarach.

Smelters have likewise their *stone-pyrites*; to understand which, it is to be premised, that *stone* at the huts denotes that crude, semi-metallic body,

or

or that regulus, concentrated by smelting the coarser sorts of ores, and denominated either from the operation of *crude smelting*, or from the lead and copper, as the one or the other of these happens to predominate. In the operation called *crude-working*, the small or poor, quartzy, rocky, mock-leady ores are, without roasting, scorified, drained and concentrated, by means of the *pyrites* naturally adhering to the *mixt-work* or ore, or of what is purposely added, into a narrower or smaller compass or body, from their otherwise unseparable and barren minerals; which body resembles a stone rather than a metal. The *pyrites* here employed is commonly *sulphur-pyrites*, in particular the coppery, nay, copper ore itself, if to be had. There is nothing extraordinary in this stone, only the name *pyrites* has been given to it by custom.

If from the internal we proceed to the external consideration of the *pyrites*, we shall find them of various figures and colours; as round, angular, oblong, flakey, &c. and white, yellow, &c.

The figures of *pyrites* being extremely various, the following are the principal:

I. *Pyrites idiomorphos*; which is, 1. spherical, or hemispherical; in this last form it is generally found radiated and lamellated; oval, clustered, cristated. 2. Angular, consisting of four or six sides; and this last cubical or tessulated, oblong, rhomboidal, cellular, or honey-combed; of eight, ten, twelve, fourteen sides, prismatical, trapezian or irregular. 3. Bracteated or tabellated. 4. Fistular or piped.

II. *Pyrites synmorphos*. 1. Lithoxiloidical, as if fibrous, or pyritified wood. 2. Conchitical. 3. Cochlitical. 4. Cylindrical or Belemnitical. 5. Turbinital, or Pyramidal. 6. Conical. 7. Astroitical.

These various figures of *pyrites* are reducible to round and angular; unless we except the foliated,

24 . *The several S P E C I E S*

and those that consist of parallel threads or fibres ; the former appearing as so many accumulated leaves ; tho' not separable into tables or plates, like spad or Muscovy-glass ; the latter, as so many fibres in a muscle, or piece of wood, tho' not actually to be parted into such, as having received that appearance only from the piece of wood that happened to lie near them. Nay, the spherical themselves consist of pure radii or cones, whose ends jutt out beyond the external spherical surface, and there exhibit all manner of eminences, as may be seen by the smoothest sort, without a magnifying glass ; such are the Hessian, and those of Toplitz and Altsattel. But the half-round and the kidney formed, as those at Friberg called *cobald*, consist not of radii running from a center to a circumference, but of shells or coats, that lie upon each other ; or whose radii run parallel, and to different points, consequently forming no genuine sphere. Of the angular, the four sided is the rarer sort ; still rarer is the pyramidal four-sided ; where a narrow side serving as a base, the other three equal sides run to a point. A six-sided *pyrites*, on the contrary, is more, nay, most common of all ; with angles often so accurately squared, as if done by rule. Such I have had in particular from the Bannat of Temeswaer and from Pretschendorff ; tho' not all so exactly square, but that there were some rhomboidal, some quite irregular, with here and there sides depressed, angles often broken off.

In general, we are to observe of the cubical (the several sorts of which hitherto mentioned often lie together, as at Pretschendorff) that they chuse beds, where there are none of eight or more sides. The six-sided cellular or honey-combed sort is remarkable in this, that the cells are so adaptedly filled with pieces of *Glitter*, as to shew like a set

of

of loose teeth, accurately fitting the sides, as if set with the greatest care.

The round *pyrites*, as was before observed, is either spherical or hemi-spherical. The spherical, or whole round, have in the middle a point, from which shoot radii to the circumference, where these radii always project, either in smooth bodies, or in sharp points, often undistinguishable; and again, often striking the eye. The hemi-spherical, which are those arched, or bulging on one side only, are partly radiated, partly coated; both commonly consisting of an impure, namely, an arsenical sulphur, and being also somewhat coppery; whereas the whole-round are generally without either arsenic or copper, and therefore yield the purest sulphur and iron-vitriol. Besides these there is also a broadish, oval, round sort, usually called *pyrites-kidnies*; also a *botrytes*, or clustered sort, consisting, as it were, of pure, small globules (whither also are referable the cristated sort) and such configurations we often meet with in the *blood-stone*, or *glass-head*: the cylindrical sort are cast in the shell of that sea-fish, from which the *belemnites* takes its figure. The cone-round, the *cochlites*, &c. have some sea-shells, in which nature has lodged and formed them, for the ground of their figure.

Scheuchzer has observed many of these round *pyrites* in Switzerland, washed down by rains and water-floods from the heights of the Alps, and supposed to be *lapides fulminares*, thunder-stones; not smooth, but unequal and rough; of a rusty cast, appearing radiated upon breaking, and glittering of the colour of gold and silver*. But he should have told us whether it was on account of their contents, or their colour, that he calls them coppery (*pyritas æreos*) as I have not hitherto observed

served a spherical *pyrites* that was coppery. In the island Staritzo, a like sort, of the size of oranges and lemons†, is found.

To illustrate the figures of the *pyrites*, in varying which nature takes a peculiar pleasure, it may be proper to consider those of other ores. Gold-ore, as such, is a rare thing, consequently it is difficult to ascertain any peculiar figure of it; the gold that is found in certain sands, clays, and other earths, in flints and stones, being rather in a native than ore state, as in spangles, foils, and grains. Silver-ores, as the *glassy* and *red-goldish* sort, have their peculiar figures; though the latter more than the former, frequently exhibiting ten or twelve sides, but they are oftenest found prismatical, like long angular staves or bars, yet of unequal sides, and like mountain-crystal, terminating in four or five unequal-shaped ends. 'Tis remarkable of *glassy ore*, that it is generally found of a cubical form, and regular enough; a circumstance never to be affirmed either of *red-goldish*, or any other ore, if you except *lead-glitter* or *galena*, and a kind of Swedish iron-stone of the nature of *glitter*. The white goldish ore may be deemed a copper, rather than a silver ore; and so indeed may the other two, from their yielding large quantities of copper. Iron-ore, or, as it is called, *iron-stone* (to distinguish it from *iron-pyrites*) generally consists in shoads or fragments, in *squats* or flat veins, exhibiting no peculiar figure, if we except that called the *glass-head*, or *blood-stone*, distinguisable partly by its spherical, partly by its hemispherical figure, and its brown-red, or russet hue, and thence denominated *botrites* blood-stone. Now as no other metal besides iron, is, in its ore-state, of a round figure, except that of *iron-pyrites*,

† *Straußii itinerarium*, p. 97. Confer. G. Agricol. in fol. p. 658.

tes, this circumstance cannot be deemed entirely accidental, but as what deserves our closest attention. Lead-ore, especially the sort called *glitter*, (*galena*) is always six-sided, partly cubical, partly oblong, and never observed of any other figure. That peculiarly rare lead-ore, which being commonly whitish, greyish, and greenish, holds no silver, not unknown at Tschopau, nor formerly here at the Tscherper, is always prismatical, and often-times flaky, like a *spad*. Tin-ore principally manifests itself in tin-stone, also in some granates. The former are mostly regular bodies enough, from ten to twelve sides; the latter are never regular, but with unequal angles and sides; some of them are pretty flat on their surface, and with angles only cut a little, or often quite away, and this either quite flat, or soon running into sharp points. Quicksilver-ore, which is principally cinnabar, has, besides its uncommon red colour, no native, peculiar figure; though quicksilver be in itself, by means of art, transformable into a thousand shapes: the reason may be, our not being always able to distinguish it in ores, or to strip it of its mask; to me it seems very probable to lie concealed in arsenic, and the like volatile, metallic bodies. Antimony-ore greatly resembles cinnabar, like it consisting of *spicula* or needles; with this difference, that in the latter the *spicula* always run parallel, but in the former they often appear like radii converging to a centre. Hither also are referable, with respect to their configuration, the beautifully red, steely-close *cobald-bloom*; the red antimony-ore; the iron-coloured, radiated *wolfram* of Altenberg in Misnia; also another russet sort from the same place, which is highly arsenical, and lastly, several bismuth-ores; seeing such distinctly manifest a radiated texture.

Precious stones may, with respect to their various figures, be supposed to approach somewhat nearer to the *pyrites*. The mountain-crystal, that is, the diamond white transparent sort, as surprising as it is common in our mines, assumes all manner of figures ; tho' the more common be either the cubical, or the prismatical figure ; this last running to a point with five unequal sides and angles. Topazes, hyacinths, emeralds, sapphires, and the like variegated stones, generally affect a cubical form : Tho' indeed the granate usually is seen to have twelve and fourteen sides (a thing not common for the other precious stones) and never to be prismatical. 'Tis however to be added, that the granate (whether all I know not) is something more than a stone slightly tinged ; it is rather richly saturated with some metal, particularly tin, whether with gold is not so evident ; so that it may justly claim rank amongst genuine tin-ores. Of the prismatical figure, we find at Stolpen in Misnia a hard iron-coloured, black-grey marble, called *Basaltes* (*a*) touch-stone ; of seven, six, five, and sometimes only four sides, and of such length and thickness as to be set up on end in the corners of streets and near houses. Of the like figure are the stones near the draining-hut of Grunenthal, in the road from Brandau to Gerkau. Of a triangular figure are the *quartz*, or flint of Anholt, an Island near Jutland ; of which the learned in Denmark make mention, but which I never saw, any more than other stones of that figure (*b*). Lastly, with regard

(*a*) *Basaltes* derives either from *Bataniā*, I explore or try ; or from *Bisaltia*, a country of Macedonia ; and then 'tis the same as *Bisaltes*. *Gesner*, p. 21.

(*b*) *Insula hæc, inquit Olaus Borrichius, in sinu Codano infinitos habet filices nigros, albos, varios, in fabulo hinc inde sepultos, at sex transversos digitos in longitudinem protensos, latos digitum unum, omnes tricquetos, ac si manu artificis fuissent*

gard to copper-ores, I have, from manifold experience and observation, made this remark, that such *pyritæ* as yield no copper, are always round; those that contain only a little, of eight sides at least, and those that are richly stored with copper, commonly exhibiting ten, twelve, and more sides.

In a word, so far as my experience in ores and stones reaches, no one sort exhibits a greater variety of figures than the *pyrites*: and whatever figure nature gives any particular species of bodies, such it continues to have unchanged, nature seldom or ever swerving from the rule she has once laid down to herself, in any particular species. For instance, a *copper-pyrites* is never round, a pure *iron-pyrites* never angular, least of all polygonal; a *glass-head* never like a *glitter*; a *tin-stone* never regular, &c. The reasons for which must be necessary, not accidental, and well deserving our careful attention and observation; for the structure and configuration of minerals may be considered as so many peculiar marks and *criteria*, from whence a better judgment may be formed of their nature, and consequently a more distinct description and history of them be attainable, at least as to their external appearances.

That division and distinction of *pyritæ* taken from their colour is a capital one; then I reduce them to three sorts, viz. white, yellowish, and yellow.

In considering the colours of mineral bodies in general, we are to observe that ores are metal impregnated with sulphur, or arsenic, or both: and this is sufficient to constitute the form or essence of an ore,

fuissent accuminati; & lateribus plerumque in illam faciem excavatis, ut Josuæ servire potuerint cultris fæxæ filiorum Israhel circumcisioñem imperanti. Act. Hassiens. T. IV.
P. 177.

ore, whatever other accompanying parts there may be in it. Sulphur is observed to reduce the white metals, and the semimetals, as silver, lead, regulus of antimony, to black, or black-grey bodies; namely, to a *glassy ore*, a *lead-glitter* and an antimony; with mercury alone changing to a beautiful red. The red metals, as iron and copper, it turns to a yellowish and yellow mass, which is our *pyrites*. Arsenic leaves white what naturally is so, and blanches or whitens what is not so. Tin it exhibits in its native white character, as appears from the tin-stone. Iron it brightens, as we observe in *Mispickel*, whose native earth is an iron. Copper, tho' naturally red, it thoroughly tinges with its own livery, as sufficiently appears from highly arsenical copper-ores. Silver it changes red, a remarkable instance of which we have in the *red-goldish* ores. For producing the yellow, brown and black casts in some tin-stones, some sulphur must accompany the arsenic, to account for an appearance so opposite to that of tin and arsenic. To avoid prolixity, I shall only hint, that arsenic and silver, sulphur and quicksilver, also sulphur and arsenic, do together exhibit colours extraordinary red. In *lead-glitter*, *glassy ore*, antimony, and *red-goldish* ore, the proximate cause of their colours lies in none of the parts whereof these bodies consist, but is first produced by an intimate action and reaction of these parts among themselves. In the others, and in many genuine ores, we observe the parts introduced bringing along with them their proper colour; particularly in the *pyrites*, where the sulphur loses not its yellow character; and the *iron-pyrites* turning only a little pale from the greyness of the iron; in *copper-pyrites*, on the contrary, the colour being heightened, from the common experiment of a red always heightening a yellow: arsenic is the manifest

nitest cause of the whiteness of the *misspickel*, or *arsenic-pyrites*; also of certain copper-ores, in which it exceeds the sulphur in quantity.

The three above mentioned capital colours of the *pyrites* are to be taken in a comparative, not a separate view: for, the *sulphur-pyrites* being viewed apart, shews white or grey; but placed near the *misspickel*, its yellow cast shews to greater advantage: in like manner the yellow ceases to be distinguishable, unless compared with the yellowish. The reason is, that these are three not very opposite colours, but easily running into each other, without destroying, tho' lowering or heightening, one the other: again, they stand in such a degree of mutual affinity, that many others different cannot be placed between them. These colours are to be understood as entirely penetrating into the substance and body of the *pyrites*; consequently they are not owing to the adjoining mineral, which indeed often strikes the eye in such a manner, that the *pyrites*, especially if lying interspersed therein, cannot well exhibit its natural colour; some caution also is necessary to prevent being deceived by the variegated, the red and green, the gold-yellow, the blue, &c. colours, which sometimes settle upon, without penetrating into the fibres or strings of the veins, and are usually called *copper-blooms*: to which must be added, that *pyritæ* being long exposed in the weather, change their external colour; whence it is possible to be misled by that powdery coloured substance, which is either ochre or verdigrease, arising in part from the destruction of the *pyrites*, and lying externally upon it, without making a part of its essence or composition.

This division taken from the colour will, upon trial, be found not only easy and distinct, but comprehensive of all the variety of the *pyritæ*. There may,

may, 'tis true, be samples, not perfectly coming up to any of the abovementioned three colours ; one yellow may happen to be higher than another, nay, needs must, as not agreeing in their contents, namely copper, to which the yellowness is mostly owing. The same holds of the yellowish, wherein often there is no arsenic at all, often very little, and often a great deal ; now the arsenic lowering or bringing down the yellow, 'tis not possible to fix this colour to an indivisible point. The white alone is the most constant colour, as being owing to the arsenic ; having observed that where it is lodged in the proportion, it bears in the *arsenic-pyrites*, not only the sulphur, which might somewhat alter the colour, must be entirely excluded, but the copper also. But these differences in colour are so very minute, as scarcely to be distinguishable ; the three, that have been assigned, being to many difficult enough to discern with exactness.

The white *pyrites* is in essence or nature only the *poison-pyrites*, the *arsenic-pyrites*, the *misspickel* and *misspilt* of Friberg, and in external appearance not easily distinguishable from the *white-goldish* ore, the *smalt-cobald*, especially the latter, though darker, internally differing much among themselves. The genuine smalt-cobald agrees, 'tis true, in its volatile portion, namely, the arsenic, with the *arsenic-pyrites*, but in its fixed portion widely differs ; seeing the true cobald smelts to a beautiful blue glass, which the *arsenic-pyrites*, on the score of its iron refuses. Cobalds are of two principal sorts. 1. That yielding the finest smalt, and appearing of the darkest grey, so as to be easily distinguishable among the *misspickels*. 2. A sort somewhat brighter, found also among the other, in lustre almost vying with the *arsenic-pyrites*, only a small matter darker than it ; and yielding by far

not

not so beautiful a small or blue colour, as the other.

The white goldish ore, to which may also be referred the white ore, the fallow ore, and the fallow-copper-ore, in colour almost resembles the fine cobald, only smoother and thus more glistering, and with the greatest difficulty distinguishable from the white-pyrites. The white ore, which at the Halsebruke is usually called a rich copper ore, tho' far short of the white-goldish in goodness, is only a fallow-ore. Fallow-ore, which is a grey silvery copper ore, and fallow copper-ore, which is a copper-ore poorer in silver and richer in copper, are generally darker than the white-goldish ore, the fallow copper-ore being the darkest of all, whence it is easily known from the white pyrites, provided you can rightly distinguish it from the cobald, particularly the second sort, and from the white-goldish ore. There is a kind of antimony-ore from Schlaitz in the Voigtland, often so little radiated, as scarcely to be esteemed an ore of that kind, yet of so dark a grey, as never to be confounded with the white pyrites, the white goldish, the cobald and the fallow ore. To range the ores, hitherto mentioned, by the several degrees of their lighter and darker casts, and to begin with the lightest, they stand thus: First, the white pyrites, then the cobald of the second sort, next the fine cobald, then the white-goldish ore, the white-ore, the fallow-ore, and fallow copper ore. A person, not carefully comparing together and accurately examining these ores, may easily mistake, but a person of experience can directly upon sight distinguish, without the trouble of comparing them; and yet there are real differences, which may afford sufficient direction to a learner to make a distinction between such ores. At least the arsenic-pyrites does, in regard to the yellowish, or sulphur-pyrites, and

to the yellow, or *copper-pyrites*, rightly claim the title of *white-pyrites*; as compared with these it certainly shews white.

The yellowish and yellow *pyrites* are not near so hard to distinguish as the white. The former is a sort consisting of sulphur and iron, and having little or no arsenic or copper, and in different views, now called *sulphur-pyrites*, again *iron-pyrites*, and at Friberg simply *pyrites*. It manifests a middle colour between the true *copper pyrites*, or the *pyrites-copper-ore* and the white *pyrites*; which colour can neither be called a white nor a yellow, but a yellowish, and discoverable upon comparing the white and the yellow therewith; as in regard to the white alone it must be deemed to be actually yellow, and in regard to the yellow alone, actually white; observing to learn to distinguish it from the dark vein-stone, the dark ores and minerals in mines, as mock-lead, glitter, &c. where its yellowness cannot strike the eye; and to guard against being imposed upon by the external, often gold-colour, which is only superficial; remember to break the sample, and judge of it as it shall then shew internally coloured.

The yellow *pyrites* may be easily distinguished; its peculiar characteristics are the copper and sulphur it holds: its yellow nearly coincides with a *fisken-green*, which might induce one to call it a green *pyrites* rather. But as in the colour, called *fisken-green* the yellow is the ground-colour, a little green only serving as a heightening; and as the second or middle sort of *pyrites* must have been called a yellow and not a yellowish, which the eye opposes; and then as the adjunct, green, might not have been so expressive, but apt to mislead to the mistaking it for a very different ore and mineral, done over with a copper-green or verde-grease; these are sufficient grounds for acquiescing

in the abovementioned distinction of colours. At least the appellations, yellowish and yellow, are sufficiently expressive, to cause no mistake in the application of them. And provided we know how to distinguish the white *pyrites* from the abovementioned white or white grey ores, particularly the cobalds, which cause the greatest difficulty; there will be none at all, upon sight of the yellowish and yellow, or brass colours in ores, securely to pronounce such bodies real *pyrites*; as there are neither yellowish nor yellow ores, that are other than *pyrites*, consisting of sulphur, iron and copper.

In some authors we find the appellation *wild* applied to *pyrites*. *Wild*, is a term much used in mineralogy and applied to waters, ores, rock and stone. *Wild waters* are such, as weaken or spoil a brine or a mineral water. A *wild stone* or *rock*, what neither holds any ore or metal at all, or not the metal we look for. In like manner may the *pyrites* be called *wild*, when not answering our purpose, either for gold, silver or copper; as a gem may be properly called *wild*, which fails either in colour, purity or firmness; * is soft, pale, dirty, plumose and clouded.

To the *stone pyrites*, procured from the operation of crude-smelting, and containing pure sulphur and iron, is usually opposed the *speise-pyrites*, an arsenical, semimetallic regulus, properly called *speise* and procured from arsenical *pyrites*.

The abovementioned divisions of the *pyrites*, taken from their nature, figure, colour, &c. have, as was said, their peculiar reasons, and may prove of use in natural history; not only for understanding the old writers, but the different methods of

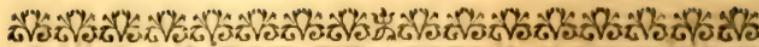
* Rößler's Bergbau Spiegel. p. 114, and 151. 7.

treating the *pyrites* itself; the ore-smelter having his *stone pyrites*; the sulphur-master, his *sulphur-pyrites*; the vitriol-boiler, his *vitriol-pyrites*, &c. tho' they all mean one and the same thing: for the *sulphur-pyritæ* both yield a good *crude-stone*, and are also proper for making vitriol.

The appellations, borrowed from the iron and copper, distinguish the metallic contents, and consequently the grand principles of their respective minerals; but may be apt to mislead, as implying iron not to be the ground-earth of all the *pyrites*; and excluding the other principles, viz. the sulphur and arsenic, which are quite lost in these appellations. The external figures do certainly denote something peculiar, which the colour may not: for from my own experience of various *pyritæ*, I may boldly affirm a spherical sort always to contain pure iron and sulphur without any the least copper or arsenic; yet hence it follows not, that the angular *pyritæ* always hold copper, seeing they partake of iron equally with the round; nor can we always distinguish whether a sample under examination be a part of a round or a half-round *pyrites*, which last holds copper considerably, or at least is not unmixed with arsenical parts. Consequently, so far as I have hitherto considered the matter, I find myself obliged to drop the figures and adhere to the colours, as affording the most proper division of the *pyrites*, and better denoting their internal properties, which the figures rarely do; the white *pyritæ* undoubtely containing arsenic, the yellowish, sulphur, the yellow, copper. And a person much conversant in ores, will, upon sight, be capable to pronounce, whether the former consist of pure iron, or, of copper too, and the proportion of each; the business in this case resting on the various degrees of one and the same colour, not to be described by words, but learned by a repeat-

repeated inspection and comparison of samples. The following circumstances however may help our observations thereon; the more the yellow inclines to a siskin-green, the more dead and less glistering it is, and the closer more clear-grained and firm the sample, richer the *pyrites* proves in copper.

It has been already remarked that the whiteness of the *pyrites* is a sign of its arsenic, and I might add of its iron too, but that there is a single, yet rare, instance standing as an exception: at Chemnitz or Stolberg in Misnia, there is a whitish *pyrites-copper-ore*, holding at the rate of £ 40 the quintal, plainly distinguishable from *misspickel*, in its pale colour, compactness and firmness, tho' in a manner not to be described; however as its whiteness is owing to its arsenic, it still remains a general proposition, that arsenic imparts that colour; tho' it be difficult to distinguish the whiteness fastened on the copper in this uncommon instance, from that on iron in the *misspickel*.



C H A P. IV.

Of the BEDS of the PYRITES.

THE yellowish or *sulphur pyrites* is met with in all manner of stone: 1. in *quartz* or *flint* it readily lodges; this very close, firm stone generally affording beds, and directing to ores, that when once discovered, the Miner imagines himself to be, if not in the actual possession, yet in the tolerably certain hope of meeting with an ore; it also forms the *selvages** of Veins, and encompasses the *pyrites* as so many shells or coats. The *pyrites* often adheres externally to *quartz*, as if run or melted upon it, or sticks like grains or buttons, or like sand strewed on it; as is particularly observable in the beautiful colours of the *copper-pyrites*.

2. In Marbles, called in the language of Miners, *korn-stone*, and resembling *quartz*; except that the former are generally white, seamy, veiny and flakey; the latter for the most part coloured, as brown, yellow, red, grey, black, &c. and moreover are not so remarkably veiny, but closer and consequently fitter to work. I have more especially observed the *pyrites* on red and yellow jasper, chalcedon, and the like, which are not unduly classed amongst marbles.

3. In

* A vein has its bed and cover of rock, both which are parted or discontinued on the sides of a vein, and these sides covered with *quartz*, or with a finer kind of mold; and this is what Miners call the *selvages*.

3. In *spad* which is directly opposite to *quartz*, being a flakey, crumbley, shivery, calcarious stone, more frequently entirely white, but sometimes of a brown-red or russet, as well as of other colours, and softer than *quartz*; so as to bear being shaved with a knife, nay often with the fingernails; whereas *quartz* often approaches to a diamond in hardness; tho' *spad* be heavier than *quartz*, to a degree of giving a strong suspicion of its holding a metallic body, little or no metal hath hitherto been procured from it; this species of stone having conceived more of the mercurial, metallic earth than of the quartzy, glassy, first earth of Becher; now in and upon this *spad* the *pyrites* as readily fixes, as it is common in our mines. I have had several instances of *pyrites* in tiny vein-stone, where Muscovy-glass, a species of *spad*, usually breaks.

4. The *pyrites* lodges also in lime-stone, gypsum, alabaster, &c. Not *vein-wise*, but rather *nest-wise*, and *kidney-wise*, unless where other veins, carrying along with them *pyrites*, happen to traverse; as appears from the calcarious *shoad* of the Schloßberg near Toplitz.

5. *Shiver* not only holds *copper-pyrites*, or *copper pyrites-ore*, as being what is common to it, but also *iron pyrites*; there having been sent me a sample in particular from the Shiver-quarry near Goslar, where it forms a genuine flat-layer or squat.

6. *Pites* lodges also in stone-coals, a thing not to be wondered at from their great affinity, as both have sulphur in common, which abundantly appears from the stone-coal works at Pesterwitz near Dresden.

7. In sand-stone, of which those brown-red, ochry, iron-rust nests observable in stone quarries are sufficient evidence: and in particular at Burg-

thanee in the territory of Anspach we find a dark, ochre-brown stone, concreted of sand, or a sand-stone and *pyrites* particles of the size of hemp seed, some smaller, some bigger, of eight sides.

8. Of *pyrites* in lime-stone we have incontestable evidence from the famous lime-stone quarry of Querfurt, from the Schlossberg of Toplitz, and in particular from the Beyerberg in the territory of Anspach, immediately beneath the under-turf earth.

9. In loams and clay pits *pyrites* is often met with ; the Hessian iron earth shews this : and the Pretzschendorff *pyrites* lies towards the *day-squats* in a fatty, *talcky* vein-stone.

10. We find *pyrites* in a kind of marly stone, a fatty, clear sort of stone-earth, commencing a stone, yet not ceasing to be an earth ; as may be seen at Toplitz, and from a large quarry at Cottitz in Bohemia. *Pyrites* lodges also in *gemss*, a soft, flakey stone, lying between the inner, hard rock and the outer garden mould.

11. *Pyrites* we find in that rocky vein-stone striking out to the *day*, called by miners *knauer*, and to be denominated a wild, barren, dead stone, from its not yielding any metal.

12. *Pyrites* usually manifests itself in and near all the wrecks or remains of the Deluge, but oftener in the fragments of minerals than vegetables ; and in what are called the mussel, periwinkle and horn Works ; as the country about the Wirtemberg Bath at Boll plainly shews in a vast variety of samples. And Dr. Balthasar Erhard of Memmingen has furnished me with Samples of *cornua ammonis*, *peletinates*, *cochlites*, *conchites*, *belemnites*, *lapides judaici*, &c. either filled or over-laid with *pyrites*. And indeed it is found not only in and upon petrified pieces, but on such as have remained unchanged, only become

some-

somewhat calcarious, tho' still retaining the nature of their proper kingdom. I have procured from M. Rosinus of Munden a piece of *pyrites*, that manifestly shewed it to have been wood, not only by its texture and growth, but actually having some of its original adhering to it ; tho' a mussel or other shell is by its nature better adapted for the conception of *ore-weatherings* or damps, even in its unchanged form : and Lister (a) mentions a *pyrites ligneus* in Ireland, supposed to have been ash-wood, turned to a load-stone of the firmness of marble.

So that there is scarce any ore or vein without the *pyrites* constituting either a principal, or at least an incidental, if not the whole part of the composition. Gold-ores we have properly none in Misnia : and as to the foreign, namely the Hungarian, I can form to myself no regular conception thereof : I have been shewn a sample from Schemnitz, yielding some silver, but upon a narrower inspection there appeared a variety of veins ; as I have often observed *glassy* ore, *red goldish* ore, *glitter*, *mocklead*, *copper pyrites*, *iron-pyrites*, *yellows*, *blacks*, *goose-dung* ore, *cinnabar* ore, all within the compass of a small stone, weighing only a few loths (b) or some of these sorts lying one on the other, and so intermixed as often to be scarce distinguished by the eye tho' assisted with glasses. This I have observed that the *copper-pyrite* of Hungary answer best. But if I take to assay for the perfect metals a pure iron, and thus an entire clean *pyrites* (for the copper yield does not properly belong to the essence of the *pyrites*) as I have had such from Schemnitz I have found the result to be nothing at all. But under the appellation gold-

ore-

(a) De Fontib. Med. Angliae. p. 23.

(b) A loth is half an ounce.

ore we must not include a corporal, native gold, which particularly in Transilvania we surprisingly observe sprouting out of, or wedged into a clean *quartz*, without the least distinguishable trace of an ore or vein lying near it, as being already a native metal; whereas an ore, on the contrary, holds the metal in a quite different form, being blended with various sulphureous, arsenical and other matters. There is a certain kind of *quartz* or flint exhibiting on its fissures a rusty sort of iron, which might be taken for a gold-ore: but 'tis to be doubted, whether this rusty matter will, after parting the gold-spangles from it, yield any metallic contents: and 'tis known, that a native metal may lie in *mixt-work* in so light and tender a form, or by the operation of stamping be so reduced to a dust, as that the noble metal cannot be *sludged**¹, but be carried away by the stream, and lodge among this ferruginous matter, which is taken for proof. And as to the eduction of gold out of *mixt-work* of more than one sort of ore, inseparably run into each other; the question will be, whether the eduction depends on one alone, or two or more of these ores; or whether it holds not here, as with many minerals, nay pure earths, which of themselves containing nothing of the noble metals, yet mixed with other ores, which also separately give nothing or contribute but a certain proportion, prove *yieldy*, as I have with certainty experienced of chalk in particular, and other sorts of earth. In such proceſſes I know not whether I should call the produce a *maturatōn* or a *transmutatōn*. This at least.

* In the operation of washing ores mixed with earthy rocky and other light matters, in order to the separation of these last; the heavier metallic parts subsiding to the bottom are called *sludge*; in High-Duth, *schlich*, whence our English, *sludge*, seems to have been derived.

least holds true, that between eduction and production there is a great deal of difference,

But in order to determine, whether *pyrites* lodge with gold ore, we must first ascertain the proper sorts of real gold-ore. For *glassy* ore, *copper* ore, and the like, which in Hungary above other ores, (for instance, above those of our mines) are goldish, are properly silver and copper ores, their ground-substance consisting of silver and copper, and their gold being only incidental, seeing without disadvantage to their principal constituent parts, the gold in these may be little or none at all. And should such be accounted gold-ores; 'tis well known that not only *iron-pyritæ* break on all hands of such veins, and that copper-ores, which are themselves *pyrites*, principally affect and exhibit gold, but also that near and upon white *pyritæ* we often find native gold.

Pyrites most readily lodges near silver ores, as the *glassy*, the red and white goldish sorts, which may properly be called silver-ores; yet near these rich veins lodging as a copper rather than as an iron *pyrites*; and where it proves the last, as an arineical or cobaldish, rather than an erratick *sulphur-pyrites*, as I have observed from numerous samples. What is remarkable, I never observed a native silver, whatever pains I took to enquire about it, either on the white, the yellowish or yellow *pyrites*. Two single samples only I have been shewn, tho' properly not referable thither; one, a *pyrites-die* or marcasite, traversed by a silver wire or rather a silver wire encompassed with a *pyrites*; the other, a piece of a *pyrites* partaking of a silver ore, of the *glassy* sort, from our Obergeburge. The silver neither lies on, nor grows out of the first, but must needs have exisite there originally, and afterwards by means of the subterraneous weather or damps happened to be encompassed by the *pyrites*. The second

second was far from being a pure *pyrites* being plainly enough mixed with the above silver-ore ; which, and not the peculiar substance of the *pyrites*, was the ground, whence as from a root, the native silver, upon a narrower inspection, appeared to proceed. And how can we expect to have silver growing from *pyrites*, when we know *pyrites*, as such, to hold little silver, its silver generally amounting only to $\frac{1}{4}$, $\frac{1}{2}$, 1, at most 2 drams the quintal, and consequently no silver growing out of it : And hence may be deduced these useful truths ; 1. that *pyrites*, especially the pure sulphur and iron *pyrites* cannot be the mother, or producing matter of the nobler metals, as many might imagine from its universal spread; for instance, here in Misnia, it always accompanies silver-ores, and appears necessary to their generation and encrease. 2. That in judging of veins and ore, we are not to suppose that matters accompanying, or even intangled with each other, proceed the one from the other ; but we are rather to look on their substances, either produced at the same time, or meeting together afterwards. And if *pyrites* have no generative, they can not be endued with a *conceptive* power for silver. Grown or native silver, so far as I know, and have had instances, is found on *quartz*, *spad*, *shiver*, *kneiss**, *ochre*, *jasper*, and all manner of *borne-stone*, on *gemss* and *glimmer*, on common quarry stone and *knawer*. Among ores, chiefly on *smalt-cobald* (to find it on *red-goldish*, *glassy*, and *white-goldish* ore is not uncommon) a peculiar instance of which we have in the *smalt-cobald* of Lacray in Lorrain. Fibres of silver are also sometimes found in and upon iron-stone ; but on *pyrites*, either white, yellowish, or yellow, as such, never, or at least it has not hitherto been heard off.

There

* A black, fatty sort of vein-stone or rock.

There is no instance of it on lead or tin ores. And the *foil-silver*, manifestly sprinkled on the glimmery granate-ore from Norway, lies rather on the fissures or fibres traversing this vein-stone than on the granate.

The same may be affirmed of native gold, and the like attention is to be used in judging of the gold-samples. Yet so far does gold differ from silver, that it is usually to be met with on white *pyrites*; of which it may at least be said, that it is peculiarly fitted for the conception of gold. Again, native silver is chiefly lodged with arsenical ores, excepting white arsenical *pyrites*; native gold in cinnabar and quicksilver ores.

In the coarse veins, as they are called at Friberg, where we chiefly look for lead and copper ores, *pyrites* more readily lodges than in silver ores. Nay in these last *pyrites* is either entirely absent, or so sparingly present, as that in many places, as at Schenceberg, Johan-Georgen Stadt, &c. the ores can hardly be worked without it, so indispensably necessary an instrument is the *pyrites* in the smelting huts.

The *pyrites* proves a sure guide to *lead* and *copper* ores, which with us are not easily separable, seeing they generally lie so mixed together, or so near each other, in one and the same vein, that it appears almost impossible for the one to be without the other: and indeed it is no easy matter to find a vein in the earth, in what direction, and to what depth soever it runs, unaccompanied with *pyrites*. And of the coarser veins, especially genuine head-veins, it may moreover be said, as those of Hartz can verify, that *pyrites* is often, in company with *mistickel* and *mocklead*, to be met with, as far as levels and shafts have hitherto reached. And tho' as a pure *iron-pyrites*, it often loses itself, yet it does not as a *copper*, nay it often is present in both forms, intermixed with *galena*, and frequently wound

wound up in, or joined close to it. The peculiar silver-veins rich in *glassy*, red and white *goldish* ores remarkably differ from the abovementioned coarse sort, as the *pyrites* generally keeps at a distance from these, nay is seldom found in the *selvages*. But I would not be here understood of veins, where some of the above noble ores are either interspersed in fissures, or *weathered* on *druse**; or lay sprinkled on the firm *mixt-work*; most of which will be found to consist of *galena*, copper-ore, *pyrites*, mock-lead, *mispickel*. The same remarks will hold good of other coarse veins.

I have observed the *pyrites-kidneys*, as they are called, to be of different sizes, some equal to musket-balls, granado's, and others even as large as cannon-balls, tho' oblong, and of a flattened round, rather than quite spherical; and generally give no tokens of being mixed with copper, whether examined by the eye or tried by the fire, yet there are some as those of Frankenberg of a flat-round, like the shell of a tortoise, that at times internally manifest some copper-ore, mocklead and *mispickel*, which the external appearance of such close bodies would give no suspicion of. And tho' the *pyrite* disappear in *glitter stock works*, as those of Hartz; nevertheless they are again found when the large stock or belly, formed here by the ore, and called *stock-work*, comes to contract again; as it doubtless must, tho' it runs, as is well known, to several small strings, difficult, if not impossible, to be traced.

From

* *Druse* in the German Mineralogy, denotes 1. Honey-combed ores, or such as are pierced with many holes, like honey-combs, by means of the subterraneous weather or damps. 2. The variegated crystals, filling up these holes again and called *metallic fluors*, or spars.

From the affinity in fundamental principles between *pyritæ* and iron ore or iron-stone, we may well suppose the former generally to lodge with the latter; as *pyrites* chiefly consists of iron, being only a sulphurated iron-stone; much as cinnabar is a sulphurated quicksilver, or antimony, a sulphurated arsenical* semimetal, called *regulus*: and indeed we find in iron-stone small cubes of *iron pyrites*, as in that of Orbis in Bohemia. And here 'tis peculiarly to be remarked, that the *pyrites* includes a traversing white limestone vein, which supplies the true *selvages*; circumstances I have also observed of the *pyrites* in the stone-coal of Peterwitz. We also find therein a *copper-pyrites*, or rather a coppery *pyrites* traversing it in veins as appears also from the same *pyrites* of Orbis. This the iron-smelters find to their cost, when not sufficiently separated from the iron-stone; the sulphur, tho' entirely forced out, leaves behind it in the iron an untoward quality: and by means of the copper, from which sulphur is with difficulty separated, adheres still more closely to the iron, and taints it (as it does all metals in their degree of malleability and metallicity) rendering it brittle and short. A coppery iron, indeed, does, when cold, manifest a sufficient degree of toughness; but when hot, it easily snaps, falls to pieces, and folders not again, and is least of all fit for making steel. That the *pyrites* lodges near that red sort of iron-stone, called *glass-head* by miners, and by drug-gists, *blood-stone*, cannot well be doubted of, tho' I never saw nor read of an instance of that sort.

Tin-

* Dr. Meuder in his Analysis of Antimony seems to allow of no arsenic in the *regulus* of antimony. Our author speaks according to the common opinion, viz. that the *regulus* of antimony is a mercury fixed by arsenical vapour.

Tin-ore, at first sight, seems to have some, tho' a distant relation to *pyrites*, by its partaking of arsenic, whereby the tin or metal lodged therein is reduced to an ore state; and in this respect, the white *pyrites* or the *misspickel* is nearly allied to it. But to shew any sulphur, which is the principal characteristic of the *pyrites*, in pure tin-ore is a very difficult matter. Notwithstanding which, the *pyrites* does not forgoe its natural privilege of being universally present, as it every where joins itself to tin-ore: and iron-stone resembles it so very much, as scarcely to be distinguished from it by the sharpest eye; so that a separation must be made by the magnet: and yet, what is remarkable, iron, which is so hard and stubborn, and also copper, incorporates with tin, which is so soft a metal; and thus may the *pyrites* in its metal-earth be considered, as easily combinable with tin; tho' by that means the tin be rendered somewhat hard, and in the language of the tin-workers, *thorney*, whence the English tin, which equally with its ore, is free from iron, is so universally esteemed.

That *pyrites* lodges with antimony-ores appears from the antimonial silver-groove at Braunidorff. In which most of the ore, together with the interspersed red-goldish ore, and some hair, also some foil silver, consists of an arsenical *pyrites*, with a little copper ore: and the entire vein, which in many places is above a fathom mighty, as miners speak, or thick, is throughout so charged with antimony, that the whole of it may properly enough be called an antimony ore. And it may here be affirmed, that tho' iron, the first principle of the *pyrites*, may suffer tin, yet by no means will it the *regulus*, which is the principal part of the antimony.

The *pyrites* is also present with the ore of quicksilver, particularly cinnabar, as in the matter of their

their sulphur these have a great affinity with each other. And I have had a beautiful sample of cinnabar-ore from Transilvania, where the *pyrites*, being quite of a steely closeness, lay within it, like a kernel in a shell.

It may in general be said, that the *pyrites* is to be met with in as different forms and position as other ores are. These are, 1. *vein-wise*; when the ore stretches downwards, oftner sloping a little, seldom quite perpendicular; and still growing wider or larger like a vein towards the heart. 2. *Squat-wise*, or in a horizontal position; that is, if not always quite level, yet hanging much and dipping a little. 3. *Nest-wise* or *kidney-wise*; that is, as so many eggs or kernels in a kind of shell, thrown together at random; without any particular connection, either with other ores, the adjoining veins, or among themselves. 4. In *stream-works*; which we may consider as so many banks or beds, caused by the deluge; they are found sometimes so very large, as to be called *stock-work* or bellies; tho' by their extension, undoubtedly belonging to the class of *squats* or flat veins. 5. In *shoads*, which are broken pieces or fragments of rock and stone, lying directly beneath the under-turf earth, and at times, by rains and floods, left quite naked; and with great violence, the effect of the deluge, washed and tore away from the veins; at length they acquire the appellation, *stream-work*, when much ore and rock, thus *shoved* or pushed away, happens to lie together in a large compass. 6. And lastly, a circumstance not the least remarkable, is, that ores are found upon *sinter*, or drop-stone, in the sides and roofs of old mines, a proof of their temporary existence, and that they are not coeval with the world.

In all the above forms may the *pyrites* be found. For, 1. It breaks in genuine constant, ore-
E veins;

veins; often entirely alone, as we have an uncommon instance at Pretzschendorff; but for the most part it accompanies other veins, as was above observed; scarce ever without mock-lead being included in the very heart of the *pyrites-dice*, as we also learn from the Pretzschendorff. The *pyritæ* setting or reaching as low as *levels* have hitherto been driven, or shafts sunk, often appear to contain copper, but soon after afford only a pure iron; thus proceeding on, till by reason of the waters, they can no longer be traced. Of this we have ocular demonstration from the Croner-mine at Friberg, and from the territory of the Tscherpe and Hohenbirk, and an undeniable proof from volcano's and subterraneous accensions; as their inflammable matter is probably, among other things, derived from the *pyrites*; which from such mountains being unexhaustible, must be distributed, not in a scanty and superficial, but in a very plentiful manner at unfathomable depths: and again, the *pyritæ* extend outwards quite to the under-turf earth, or almost to the *day*, tho' the other accompanying minerals in the extremities, or first beginnings, are wont to disappear or vanish: or, conversely, most ore-veins manifest themselves from without inwards first of all by the *pyrites*; assuring the miner, from unexceptionable experience, of his being either already upon, or not far off a capital vein.

2. The *pyrites* affect a squat or horizontal bed, as *shiver-mines* sufficiently shew; the *pyrites* always inclining to extend and stretch laterally, which is what we commonly call a *squat* or flat vein. Generally they are copper, very rarely iron *pyrites*, that affect this sort of bed: and such *pyrites-squats* are commonly without any admixture of other veins, as *mock-lead*, *mispickel*, *glitter*, &c. which is the reason that the copper from Shiver-Mines

is finer, fitter for use, and more valuable than that from mixt vein-stone. Again, stone-coal pits give an ocular demonstration to the same purpose; but here the *pyrites* is rather irony than coppery. *Pyrites* is also readily found along with lime-stone, as the abovementioned iron-stone of Orbis shews: and in lime-stone beds probably, as these commonly form *squats*; tho' I cannot affirm, I ever saw much *pyrites* there, as I have in *slever* and stone-coal.

3. This mineral has been found to manifest itself *nest-wise*, or *kidney-wise*, in proportion as the fossils, that lie near us, have begun to be more carefully examined: and thus it appears not only in loams, lutes or clays, in marles, in marley lime-stone and in lime-stone, but with this difference also, that whereas in real ore-veins it is not unmixed with *mock-lead*, *misspickel*, and consequently arsenic and sandarach; here on the contrary it is quite pure, with only its iron and sulphur, seldom any copper.

4. In *shoads*, or broken fragments of veins, and consequently,

5. In *stream-works*; as the *pyrites* may, equally with other *mixt-work*, be supposed to have been torn and shoved from their veins, and accumulated by streams or floods. Nay, according to Rosler *, Druse, Wolfram, also granates, and iron-corns, nay, even quicksilver itself, is found in stream-works.

6. It deserves peculiar attention, that in old mine-works, the *pyrites* is found grown anew on *sinter*, of which in the following chapter; a circumstance serving to convince every impartial enquirer, that the *pyrites* lying on *druse* and fissures, are, with respect to their origin, the effect of a

temporary growth, and by no means a primitive work of the creation.

7, and lastly. The *pyrites* is no ways uncommon in bodies of the other two kingdoms; such as by accident, particularly floods, have chanced to light upon proper beds, and there have petrified, or changed to earth; as the periwinkles, muscles, and other sea-shells, at Boll, in the territory of Wirtemberg, fully shew. Tho' the instances of vegetable bodies are not so very common, yet, at a considerable depth (not to mention now the piece of wood reduced to *pyrites*, spoken of above) we meet with beds, shoved, or laid one over the other, of a *pyritous* alum, resembling, both in external form, and texture, nothing more naturally than pieces of wood; nay, sometimes entire large trees.

I would not here be understood as insisting on the absolutely universal presence of the *pyrites*; for, were that the case, smelters, in some places, could be at no loss to work their poorer sort of ores: but my meaning is, that there is scarce any ore so common as the *pyrites*; no one sort of ore, stone, mineral, or earth, wherein it does not lodge; nor any mine, wherein it can well be a stranger; though here and there it is not found without some trouble and difficulty.

The reader is to be apprized, that, after the Friberg manner, mentioning *pyrites* simply, without any adjunct, I principally intend the yellowish, or, as it is there called, the *sulphur-pyrites*. The yellow, or *copper pyrites*, or copper ore, is generally found in the same beds as the yellowish; but never, so far as my experience reaches, in such round balls, or nuts; though often lying huddled together, like so many broken pieces or fragments. And should some copper slip in among the round *iron-pyrites*, yet it is never found in such quantity,

quantity, as may properly entitle it to be classed with the yellow *pyrites*, nor, consequently, with the copper ores. I never had an instance of the yellow *pyrites* in lime-stone, gypsum-stone, alabaster, &c. How the case stands with stone-coal, I know not. Sand-stone, so far as my experience goes, should have little of it: muscles, periwinkles, and the like shells, reduced to *pyrites*, never have a sufficient quantity of copper, to entitle them to rank with the yellow *pyrites*, or copper-ores. The white *pyrites* I never missed, but in shiver, 'till a specimen I once had, shewed it there inter-spersed in grains. Having long, and in vain, looked for it in lime-stone, a sample from Sweden shewed it also intermixed there: but in sand-stone, so far as my observations and enquiries have gone, I never had any instance of it.

The *pyrites* is found also in water, but neither as in its proper matrix, much less, as springing from water, as from its seed. The curious Dr. Daum, of Dresden, sent me, from the island Heiligland, in Holstein, a *pyrites*, under the title of *marcasita aurea marina*, which is sulphureous, arsenical, and also something coppery; and moreover, of a variety of figures. It is thrown on the shore by strong easterly winds, and driven back again into the sea, by westerly. It was, undoubtedly, lodged in earth, or rock, and broken loose by the waves. Dr. Major mentions some remarkable circumstances about it; as, that in the fire it will emit a kind of cinnabar, or rather, a sandarach, of the colour of cinnabar; also flowers, of an ultramarine colour; though this I never observed, nor heard of, in any other *pyrites*; nor can I imagine it should yield any such flowers. *Earth-blues*, of which kind are *ultramarine*, *chrysocolla*, *mountain-green*, and *Malachites*, are derived, 'tis true, from copper-ores, and thus from

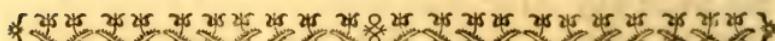
pyrites; but not by means of fire, but of the *weather*, both that above and under the earth; as we may often see, in the greatest perfection, in copper-ore flags, or *scoriae*, after having lain long exposed on heaps in the air. Further; such *pyrites* is found accompanied with Belemnites, so that the inhabitants called it *false gold*; tho' I leave it a matter undetermined, how far it deserves the title of a gold Marcasite (*a*). The abovementioned author has with it performed all the experiments of lightning, and found the metallic globules melted from it, to cause in the hand the very same burning that real lightning does, namely, a smarting, yet without any stains, or other hurt; also, in falling down, to set blotting-paper on fire.

From what has been said, it may be usefully observed, that a great deal of attention is requisite, in forming general conclusions, and axioms, even after a vast number of experiments have been made. It is extremely remarkable of the *copper pyrites ore*, that it is never to be met with in lime-stone, gypsum-stone, alabaster, and the like: consequently, that the nature of the stone and earth may serve, if not as a matrix, to contribute to, or lay the foundation for, the generation of ores, yet, at least, often to impede their production. Were there no instance of a copper ore in shiver, where, notwithstanding it is in great plenty (so very peculiarly fitted may the fatty, slimy shiver-earth be for the conception of copper ore) and in spreading *squats*, it could not fairly be thence concluded to be in none. So in regard also to lime-stone and sand-stone, wherein it is never found, we might easily imagine copper-ore never was, nor now is produced *vein-wise*, but all of it ori-

(*a*) Majoris memoriale anatomico-miscellaneum, obs. 3. §. 4.
17. seq.

originally created; as all such stones and earths, consisting of sand, of calcarious and slimy matters, the reliques of the flood, becoming afterwards hardened, were without copper-ore. And thus, propositions absolutely general, are not easily to be admitted into the science of nature: as we cannot well conclude, that because a thing has not been hitherto so observed, it neither is, nor can be so. That a thing exists, and in such and such circumstances, we may assuredly affirm, but that it cannot be in any other than these, would be indiscretion to assert. And with this I might justly charge myself, should I, from copper-ore not being hitherto found in lime-stone, thence form a general conclusion. In the mine-history we have many very curious remarks, deduced from much and long experience: for instance, that such and such circumstances, and the appearance of such and such minerals, give hopes of some ore or other; but it might tend to great mistakes, to form unlimited, absolute propositions from such remarks: for, often, the ores presumed, either appear not at all, or very different from what was expected. From the nature of the upper-garden, or under-turf mould, we attempt to form a judgement of the subjacent mould, of the presence or absence of any ore, and of this or that particular sort of ore; as if the lower contents were necessarily derived from the upper: we are, therefore, carefully to avoid being too precipitate in forming axioms and conclusions. Our business, first of all, is to make observations, proper remarks, and collect instances together, without pretending to deduce any consequences: for how superficial often are even the most accurate remarks and observations! Our experience is chance-work; our ardent pursuit after riches so much engrosses our thoughts, as to make that our only end in the

business of mining: and who is the person, that will give himself the trouble of carefully examining what even chance throws in his way, if such examination does not afford any prospect of gain, or arrest his attention by its beauty, or uncommon appearance? Lastly, who is the person diligent enough to set down, and register his observations? the omission of which, will ever render any part of natural history uncertain, and defective.



C H A P. V.

Of the PRODUCTION and GENERATION of the PYRITES.

WITH respect to the origin of the *pyrites*, it is proposed to consider the three following particulars. 1. At what time. 2. From what principles. 3. In what manner it was produced.

As to the first, it is highly probable, that the *pyrites*, as it now lies in the bosom of the earth, did not all originally exist from the creation, but that most of them have been generated at different and successive periods; which generation will, in all likelihood, continue to the end of all things. It is also probable that minerals, in general, constituted no principal part of the first creation, as the common division into three kingdoms would seem to insinuate; but are to be considered rather as something incidental, produced occasionally, as the opportune concurrence of proper materials have served that purpose: not but that within the term of the Mosaic creation, both the ore matrixes, as the firm rock, or stone, and the ores, and native metals began to be produced; and so far we may well affirm minerals to have been created: yet, to speak more

more precisely of the nature and original of the mineral kingdom, from reason and experience, we ought not to ascribe to that period all the mineral veins and fibres, we either know or conjecture to exist in the earth; nor should we imagine, that the veins of ore were at the first formed.

Doubtless, at the very beginning, actual ore has been generated in the deepest and innermost bowels of the earth, or has there first taken its rise: seeing the sea, that universal, powerful, and indispensably necessary mean of mixtion, composition, coction and maturation, had at the very first penetrated into the depths of the earth; and thus, both in the most effectual and proximate manner operated thereon; as plainly appears by the veins of ore already sought for, and discovered; these being always found so much larger, by how much deeper they run, and becoming smaller as they approach the surface; the roots and principal trunks of these last being to be sought for below. And as to roots, trunks and large branches, reason clearly suggests, that these principal parts ought to be ascribed to the first creation: and no less probable is it that those principal veins also, that have at any time been sunk for and disclosed, tho' not reaching at furthest to above 600 fathom deep, or even not to half that depth, may reasonably be derived from that period. Nay, very small veins and seams, especially if shooting from larger veins, and these again from the largest of all, may not unjustly be refered to the same origin; yet without denying their continuing to stretch, and, as it were, still shoot out into new sprouts.

Now, if we find the *pyrites*, not only an universal indicant of ores, but also at the greatest depths, nay most properly there, we must allow it, as we do other ores, and even preferably to them, to be as old as the creation. But should any one

from

from concomitant circumstances infer the *pyrites* to be the mother of all other ores, he would be convinced of his mistake, upon being apprised, that tho' they attend upon, they never are derived from each other. Nevertheless, some preference is still due to the *pyrites*; particularly its martial and sulphureous parts are such earths, as are proximately derived from the undetermined, simple earth, and to which they proximately agree. The sulphur is originally contained in such a manner in the crude, especially the slimey and bituminous earth of the sea, that to its introduction into the composition of *pyrites*, it need only be educed and not transmuted. And tho' between bitumen and common mineral sulphur some distinction may be observable; yet, 1. they are very nearly allied; again, 'tis the iron, not the sulphur, which constitutes the principal, nay the ground-part of *pyrites*: and in regard to the metallic earth, no sort of ore or metal has any thing in it, between which and an unspecificated crude earth there is so near an affinity, as might be shewn in *pyrites* and iron-stone. Hence iron is educed without difficulty from loamey, clayey and the like fat earths, by the accession or addition of the *phlogiston* constituting metals: which cannot so easily be effected for other metals, without mixing the earths employed with other things, and especially without a previous long appropriation, and taking a tedious compass about. And the iron-earth of the *pyrites* called *ochre*, so nearly resembles a common, especially a loamey earth, in texture and gravity, that it may well be deemed an earth immediately derived from it: and often their colour is so much alike, that the one might be easily taken for the other. In short, there is no metal, to whose constitution an universal crude earth more readily and nearly suits, nor which so easily reverts

reverts to earth, as iron. Now as iron is the ground and principal, constituent part of *pyrites*; it follows, that the *pyrites* (together with the unsulphurated iron-ore, or iron-stone) is the most proximate, metallic ore, which in the beginning might have arisen from an unmetallic, unprepared earth.

True it is, there are earths, which quickly bear metallisation for gold, silver, copper, lead and tin. But in the first place, 'tis here particularly to be heeded, whether for instance they constitute, as is pretended the gold and silver clays, or whether they contain only very tender and unobserved eyes or spangles of these metals: again, whether, tho' generally cryed up for their gold and silver, they yield only a very small matter thereof; as iron itself, especially if noble veins join or accompany its ore; or if in the iron there be pure native silver interspersed, it may be said to contain gold and silver; but this is not the question. Further, it deserves enquiry, whether the gold and silver *yields of finters*; or, those marley, ochry, talcky, and calcarious earths, fermenting and exuding from fissures, both in the groove, and often at the *day*, constitute their internal, proper mixtion, or only adhere externally, as in a *beap-work*; and thus mixtion and aggregation is here to be well distinguished; seeing, 'tis well known, that ores, nay native grown metals, do, by means of their *weathering*, lose their bed, and in length of time, sometimes their ore and metallic form, and revert to an actual earth; the silver to a white, the gold to a blackish and grey, which is carried off in a tender earth, in a fluid form, by the waters; and the former never, the latter often observable by the eye; and in general, on account of their great degree of tendernels with difficulty, if at all separable in the buddling or washing

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washing trough. And as the universal, crude earth, not as in the groove, but as at the *day*, seldom amounts to any considerable gold or silver *yield*; iron, on the contrary, is every where to be found in marl, clay and loam, being very tender bodies, and consequently the best adapted for metallisation; and in all underturf, or garden earth infallibly, and that in considerable quantities.

'Tis also true, that we must not deny crude earth sometimes to yield copper, lead and tin; yet more rarely than it does iron. Besides, the tin, that might be collected from the upper crude earth-layers, is not from that earth as such, but from the tin-stone, and *shoads* and grains mixed therein, and thus educed, as from *stream-works*. But according to Tollius's and Barba's opinion, it should be an earth, not only holding, but also generating tin: as the former observed not far from Joachimsthal near Gottesgabe on the confines of Bohemia; and the latter, at Potosi*; tho' instances of this sort are extremely rare. Of copper I have no such examples, if we except the coppery *gurs* or juices in mines, as arising from nothing else but dissolved, crumbled, vitriolescent *copper-pyrites*, and precipitated copper-ochres or rust, also æruginous clays or marls, which have their colour from dissolved copper. And that extremely beautiful smearable Siskin-green, to be met with near Tschopau, deserves a peculiar examination.

As to lead, besides the native grains from Maslaw in Silesia, I have had no other instance, besides what the very leady clays of the Rauten-crantz at Johan-Georgen-stadt, there called *lead-spat*, afford, and what sometimes *breaks* here at Friburg,

* Tollii Epist. itiner. pag. 96. Barbæ Bergbucklein, pag. 114.

Friberg, at the Tschelper and at Tschopau, in colour sometimes approaching the rare white-grey, and often to the extremely beautiful green lead-ore: and therefore this leady earth, which is something very uncommon, and hitherto only found in formal veins at the due depth of ores, is to be considered as an earth, already peculiarly prepared for particular metals, nay almost as a lead-ore: besides, we may conclude from the vein, which has its *selvages* entire and close, and from the extraordinary *lead-yield*, often amounting to 20 pounds the quintal, the vein was formerly an open fissure, and this leady clay, as a fluid *gur*, derived from a lead-ore, *weathered* and reduced to earth. Nay the universal, upper fatty layer of earth comes near to the constitution of iron, so that these particles of it swallowed up by plants, lose not their fitness for metal, but according to M. Lemery's experience, are reducible to a genuine iron, as will plainly appear by the magnet.

Conversely it also holds, that all metals are again reducible to earth, yet none more so than iron, as it usually falls entirely to rust, ochre and earth by the bare moisture of the air; whereas for the corrosion of copper a longer time is requisite; and for lead and tin scarce the longest term sufficient: the nobler metals, as fine gold and fine silver, neither air nor time seem capable of affecting in the least. No other metal is affected so soon as iron with the weakest *depart-waters*, which scarce touch other metals; nor are any so easily reducible to the form of earth, as iron. This may be proved by employing the same *additions* for the metallisation of metallic earths, and *calces*. To which may be added, that no metal so readily becomes vitrifiable, or is brought to the highest degree of a perfect earth. Whence the pyrites is indispensably necessary in the business of smelting,

Smelting, in order to the act of scorification or vitrification, as this last operation is for metallisation. Upon the whole, in iron the metal and the earth stand susceptible of the quickest, easiest and most repeated changes. 'Tis the first metal, that may be, and, proximately, is made from crude earth ; its earth is the first form of all metallic earths, derived from the universal crude earth ; whence as iron is the ground-earth of *pyrites*, this last should seem not improbably to have its original as high as the creation. And naturalists devising another arrangement of metals than that taken from the planets, should give iron the preference, at least with regard to priority of existence, if not of derivation ; for by the common disposition of the mineral kingdom, one metal is groundlessly supposed to be produced from another ; for instance, copper from iron, gold from copper, and in this case from *pyrites*, and in the language of miners, from mocklead and glitter ; a more mature from a more immature, and a noble from an ignoble metal.

To determine the particular time or day, on which the subterraneous kingdom took its rise, or arrived at its state, seeing we learn this neither from Moses, nor any other inspired writer, is perhaps no very easy matter. That actual mineral, metallic *mixts* should, before the second day, lie confusedly huddled together, seems not very probable.

On the second day, the dry land, as Moses calls it, began to appear, out of the chaos, and acquired its form. Now from this, and particularly the third day, on which the earth was by an express *fiat*, made fit for the production of vegetables, it is scarcely to be doubted but that the earthy particles were hereby multiplied, and the tenderest of them formed, by means of the water, for vegetation ; and the more dense, heavy particles,

ticles, rendered in some measure fit for the production of ores and metals: from ever varying circumstances and causes, the several species of stones and ores were still more and more multiplied, and have appeared in the disorder and confusion we now find them.

Minerals cannot be put on a footing with the two others kingdoms; as they consist mostly of dry, but vegetables and animals, of humid particles: the latter may, in some sort be said to be self-produced, seeing what they take in for food, is, as if by a ferment, assimilated to their juices; whereas minerals grow by a bare external accumulation; wherein every accretion is applied in layers, something like what appears in the crystallisation of salts, and in the *pyrites weathered on druse*: and what is thus once accreted never comes into motion, or if it does, not without the destruction of the subject. The encrease of bodies happens also in very different ways; vegetables and animals being regularly produced from seeds and eggs; but minerals in no such way, no one *pyrites* being thus to be shewn produced from another, but at this day necessarily arising from the very same principles with the original *pyrites* at the creation; or from *dissolved* or *destroyed pyrites*; and thus from *pyrites* and ores reduced to their first principles, whatever alchymists or others may alledge to the contrary. Earth is the mother, and she passive; on the contrary, water, as being active and what must impregnate, may be called the father.

I wave at present, insisting on the prejudice accruing to our knowledge of nature from that very unequal distribution into three kingdoms; as thereby we acquire a very false, or no notion at all of nature, and are apt to run into false conclusions about her. If minerals constitute no sister kingdom,

kingdom, but be an essential part of their common mother, the earth, how can we pretend to limit their origination to a certain day or period of time, and rather not allow their having existed, in their principal part, from the beginning, and probably from the third day of the creation ; tho' afterwards, from time to time, they were extended and became more firm and strong.

The deluge is an event, which has produced the most remarkable alterations in the earth, that have at any time happened, and to which many effects, observable at this day, are to be ascribed. The history of the deluge gives great light towards the knowledge of nature, and the present state of the earth seems to verify this event : by the violence of the deluge the mineral kingdom was thrown into confusion, parts before conjoined were separated, ores and veins dislodged, and new beds and positions given them. The several *strata*, wherein minerals are at present found, afford convincing instances, as well of the truth as of the confusion wrought by this event, especially in parts where clay, sand, shiver, stone and the like, lie in beds and layers on each other. For instance, at Waldenberg, in Misnia, famous for its earthen vessels employed for distilling and other purposes. First, beneath the under-turf earth, which is also stony enough, a coarse, stony sand lies ; underneath this again, flints, of the size of hen-eggs, and above these a clear white sand. Thirdly, a middle sand, wherein are nests of *black-stone* with *stone-marrow*. Fourthly, that extremely fat, clear clay, from 2, 3, to $3\frac{1}{2}$ German ells *mighty* or thick ; and from the under-turf earth, from 10 to 20 ells deep ; from which our smooth earthen pots, jugs, and the like vessels are prepared. Fifthly, underneath this, appears a leaner, namely, a sandy sort

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of clay, about an ell *mighty*; usually employed for making retorts, and the like vessels, that are to endure strong open fires. Sixthly, a grey sand layer, the depth of which is hitherto unknown. This account, together with samples of the *strata*, I had from a person of reputation, living on the spot. Now here the *strata* are not disposed, as if an effect of the flood, but quite in an inverted order. It is also very remarkable of the Eisleben mines, according to M. Mylius *; that we find, 1. The underturf earth reaching from three to four fathom deep. 2. Loam. 3. Red clay. 4. Blue clay. 5. Fine sand, a fathom and a half deep. 6. Red sand-rock, three fathom deep. 7. A quaggy, soft layer, twelve fathom deep, but not in all places. 8. A loose, spungy layer, three fathom deep. 9. The ashes, three fathom deep, quite to the rock: tho' these layers have happened to be disposed tolerably well in respect to gravity and lightness, coarseness and fineness. In other parts, tho' not in all, of these mines, the first layer is Sod. 2. Earth. 3. Loam. 4. A sort of common round stone. 5. Coarse quick-sand. 6. Red quick-sand. 7. Yellow quick-sand. 8. White quick-sand. 9. Black vein stone. 10. Brown wood-vein-stone. 11. Red vein-stone. 12. Red clover. 13. Red seamy vein-stone. 14. Coarse lime-stone. 15. Lime-stone. 16. Specular lime-stone. 17. Clay round-stone. 18. Loose spungy-stone. 19. *Kneiss*, &c. And tho' many *strata* of earth may have taken their natural positions, yet they never consist of entirely similar particles; and in the chalk, also in the fine clay of Waldenberg are found pieces of the black and grey chalcedon or common flint: yet the deluge has caused great alterations on the surface; as having here covered a country with pure sand, there with slime; also introduced such a degree of confusion, so as to make it scarce possible for each *stratum* of earth to be

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unmixed.

* Mylii Saxon. subterr. P. I. p. 10. &c seq.

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unmixed with any other, but for the most part to lie huddled and confounded together.

For, we are not to suppose our globe to resemble a trough, or the like excavated figure, wherein the variously mixed earths are to be regularly disposed, as in the operation of buddling or washing ores, but to be of a spherical arched form; where the waters, as on a hanging bottom, powerfully rend and pull it asunder; and this force of the waters we may suppose to be greatest at the beginning, and end of the deluge.

And here we have two circumstances in particular to consider, (1) That the *deeps* of the earth (the cavities and veins being not only broken, but enlarged) were filled both with the bituminous slime of the ocean, the various sorts of earth of the upper surface, and also, with the parts of vegetables and animals. (2) That ores, stones, and minerals, were not only driven inwards by the elevation of the under-turf earth, but also outwards to the *day*, by the eruption of the waters of the abyfs, and thrown into and among the under-turf earth; as will appear no ways improbable, from considering the violence of the bursting waters, and that prodigious load of sea impetuously rolling to and fro on the surface. Can it with reason be pretended, that before the deluge any vulcano's existed? or can their origin be ascribed to any better cause, than that, exclusive of the commonly allowed parts of animals and vegetables, it also served to supply the bituminous matter of the sea, as so much new fewel superadded to the sulphureous inexhaustible load of ores already lodged in the bowels of the earth: and further, seeing *volcanoes* are never found except near the sea, may not that immense mass of undeveloped materials serve for incessant supplies to their production?

In and under the upper layers of earth, ores appear to have been sometimes broken off from another place, pushed forth and shattered to pieces; sometimes they have been found complicated, and at other times scattered about, partly in banks or earths newly turned up, as in so many prepared ore-matrixes: and I shall leave it as an undetermined opinion, whether the belief that by the deluge actual head ore-veins, or large constant veins have been produced, be quite so absurd?

And first, as to *shoads*, or broken fragments of veins, we are not in the least to doubt of their being assignable to some violent alterations, of which the deluge alone can properly be supposed the cause. And this seems no ways improbable, from the effects of small torrents, in loosening and carrying minerals up to the *day*; this appears from the gold spangles and grains in some rivers, as in the Schwartze in Thuringia, the Goldsche in the Voigtland, and other waters; in which we often find the minerals themselves shew that they were forced away from veins. And, doubtless, we might also find the ores of other metals, were we as diligent in search for them. Great floods exert a surprising force in vallies, on opposing banks and walls, nay, on rock itself; huge fragments of them being often rolled to a great distance. But what is all this, in comparison to the mighty effects of the deluge, which has tore out of the inmost bowels of the earth, and from depths we can never hope to reach, ores and rock? at the same time, the fountains of the deep were considerably enlarged. Now, as the ores happened to lodge accidentally here and there in the earth, and were occasionally of one and another sort, close and spungey, near to, and at a distance from the great flood-fountains, so also the *shoads* chanced to prove either poor or rich.

This, certainly, must be allowed, that these shoads generally contain tin, or iron-stone, or both together; at least, no *stream-work*, consisting of pure *shoad*, is hitherto worked for other metals. If *pyrites-shoads* are not always found in the under-turf earth, this may be owing to our want of care in examining the upper earth in its several beds: for, as to *pyrites* in *flat-works*, we have plenty, both *bed* and *nest-wise*, generated either short, or long after the deluge, as shall appear below. And at Wiera, not far from Neustadt, on the Orla in the Osterland, a *copper-pyrites* was accidentally found, in digging for a cellar, at the depth of a fathom and a half; also in other parts thereabouts, upon digging down from the *day*.

Now this supplies us with some circumstances particularly meriting attention. (1) That in this case we observe neither *flat-work*, nor vein, in which the ore should take its direction. (2) That the ores are not immediately dependent on, or connected with each other, but appear in piece-meal; and though at no great distance asunder, yet, by the interposing under-turf earth, are often greatly divided and scattered. (3) That these pieces, though happening to lie pretty close together, never exhibit any appearance of their having ever been joined, as we often meet with veins, where the ore is cut asunder with fissures, and these fissures so stuffed with *gurs*, as if, by their means, the parts had been separated to a greater distance; but then, in this case, a curious eye discovers the parts to have been once joined, and that they plainly formed together an actual vein. (4) That these copper samples shew edges and corners so sharp, that if we suppose the place they are found in, not to be that of their birth, yet it could be at no great distance off, if we consider that such broken fragments may, by rolling, become smooth, and worn round.

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But we need not go so far for instances; seeing in the *tin-stream-works* of Friberg, the *tin-shoads* are often intermixed with *pyrites*, as smelters find to their cost. Should we allow the *pyrites*, from its supposed universality, to manifest itself in many places as a *shoad*; yet it must also be allowed, that this mineral, above all others, is most susceptible of destruction, and of becoming an earth again; especially if lying near the *day*, and thereby more exposed to the action of the air; so that in the course of some thousand years, many testimonies of the deluge may be quite effaced. Further, that this surmise is not without foundation, may be concluded from the rusty spots and nests found in many places; in particular, those in sand stone, shew remains and tokens of *weathered*, or destroyed *pyrites*. Nor are we to wonder, that *copper pyrites* is more commonly to be met with than *iron-pyrates*; seeing the former is generally more durable and lasting, if not sometimes indestructible.

Again, it will be no difficult matter to form a judgement, and shew the weakness and insufficiency of the remarks generally made on *shoads*. Thus much commonly holds true, that, the ponderous and most metallic sort cannot easily remain near the surface, but must sink down. Concerning pieces of ore which happen to be smooth or sharp, we may probably conjecture, whether the vein, whence they came, was at hand, or at a distance: if the stone thereof, or of the adjoining mountain, be the same with that of the *shoad*, we may imagine the vein to lie there, and there we may work for it; and *shoads* in high mountains, and on easy declivities, are more easily come at. But every one sees how fallacious such indications or directions are; for such broken fragments may, in a tender bottom, be driven to

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a sufficient distance, without having been in the
least broke off, or smoothed.

I must not omit mentioning, on this occasion, that usually, under the title of *pyrites-shoads*, we also include the *squats*, or *flat-works*, which are commonly *copper-pyrites*, and justly; as these, with their upper and under earth-layers, are couched in *strata*, one upon the other. To this Lohneiss refers *, when he says; ‘we also find ‘*squats*, which extending in length and breadth, ‘often take in a large compass of rock, which ‘we call *shoad*, &c.’ but with this remarkable difference, that on such *flat-veins*, not the ore itself, as is the case with the *shoads* hitherto described, but only the earth, whereon afterwards the ore comes gradually to be generated, is thus couched and laid.

As to *flat-veins*, these, in regard to their origin from the deluge, deserve a quite different consideration. Sand-stone, lime-stone, marle-stone, and shiver, which generally form *squats*, plainly manifest, upon a somewhat more accurate inspection, that they are a concreted sand, or hardened earth. The several figures of herbs, wood, bones, shells, and fish, are far from being *lusus naturæ*, or fortuitous images, but are, in part, actual bodies, somehow or other conveyed thither, or, at least, the impressions of these bodies. This I have shewn, from several circumstances, in my *Flora Saturnizans*; particularly from the nature of their beds or matrixes, from that of the bodies themselves, which are commonly durable, hard, and stoney. And here I must rectify a mistake I was there under; namely, in not allowing the *bystero-lithos* to be an actual species of mussels, and doubting about the *glossopetræ* being the teeth of sea-dogs;

* *Berg-baa-buch.*

dogs; but now I am fully convinced of the certainty of both: of the former, from a particular treatise of M. Verdries; and of the latter, from many instances; in particular, from my own inspection of a sample, to which there still adhered a piece of the jaw, in the possession of Dr. Buttner, of Chemnitz. Further, from the substance and nature of such fossile bodies, remaining, often, quite unaltered, their origin is plainly manifested; also from the *mixt-works*; and, lastly, from their irregular position; in reality, not owing to their natural tendency, but to some external, irresistible force; whence it is no improbable conclusion, that nothing less than the universal deluge could have buried the parts of animals and plants at such a depth in the earth.

Now as both the *copper-pyrites*, and also the often intermixed *iron-pyrites* flat-work lie in, under, and above such petrified remains of the deluge, how can we *here* possibly go so far back as the creation, and *there* begin with the deluge, or call in question the existence of such ore in that very place and spot before, and only allow its having arisen first of all after the deluge? three circumstances which, if not entirely convincing, yet, being of some weight, render the thing probable.

The first regards the *strata*, or beds of earth, constituting both the under and upper bed of the *pyrites*; some of which I have before mentioned, from M. Mylius, and others: these lie in different forms, in various shelves, or *strata*, *cover-wise*, one over the other; which we may justly attribute to an horizontal, or level motion, and this motion to a floating or wavy flood. The undermost often reach to 10, 20, 30 fathom, and more; so that they cannot be ascribed to any partial or provincial inundation: and lastly, they shew their se-

paration from the *terra firma*, or that bottom, which before the deluge constituted either the upper surface, or was, by means of the deluge, first tore up, and laid bare.

The second regards the nature of the *squat-stone* itself; for now to mention only *shiver*, in which the *pyrites squat-veins* are mostly discovered, we must needs suppose them to have been originally a water-slime, gradually arrived to a leafy or flakey stone, as was above solidly deduced from the extraneous matters found therein; it being impossible they should have their present degree of firmness and hardness, and at the same time receive such matters as these: and the nature of *shiver*, especially the aluminous, might serve not a little to establish this, as being inflammable, and like a fatty sort of slime; nay, not unusually manifesting in the fire, a flame, and odour like amber and bitumen. Nay, 'tis hard to say, whether (3) this other circumstance may not be allowed some weight, namely; as lime-stone so readily break near *shiver*, and are, above others, of a saline nature; again, as lime-stone, shiver, and stone-coal, are not easily to be found, the one without the other; also, as lime-stone has actual stone-salt lodged in and upon it, of which we have a sample at Bottendorff, in Thuringia: lastly, as the sea, particularly in its depths, abounds with saline, bituminous, and sulphureous particles: and besides, as salt and sulphur, sulphur and salt, salt and earth, stand so proximately convertible; should we not, from all this, conclude, that shiver, stone-coal, and lime-stone, may have had, from the sea, one common cause, both of their mixture, constitution, and bedding?

And as such *flat-work* ought not to be derived from the creation, still less is it to be considered as a genuine *shoad*, or *piece-meal-work*, thrown together

gether in a heap ; in regard it not only, tho' cut through with cross spads, fissures, and minerals, hangs together like a thread, but it also often appears shattered and tender as hair ; the deluge, first, only supplying the proper slimey earth, as the ground, or basis, which not only became full of fissures in the drying, but is in itself also an accumulation of a spungey and easily penetrable matter. In the fissures, the *ore-weatherings*, or damps, have found ingress and lodging ; but in the particular sort of the earth, found a well prepared, also an expansive matrix ; and for this purpose, nature has had a sufficient space of time, as being what was highly requisite ; but why she has excluded or produced no other ore but *pyrites* chiefly, in particular, *copper-pyrites*, is indeed a question we are as little obliged to resolve, as the remote causes of things are beyond our investigation : however, a cause may be assigned, on which we may bestow the following reflections.

We find both earth, *heap-work*, and stone, nay, ore too, in layers. Of the first we have, every where, instances enough ; particularly in sand, loam, and clay-pits. Of stone there neither is, nor can be so much known ; seeing both our experience and accounts thereof are lame and imperfect. In stone-quarries, however, we plainly observe layers ; yet, commonly, not so often of a different, as of a similar nature, where neither complexion, nature, nor colour, exhibit peculiar layers, only the seams form different flakes and tables, the whole mass of stone having only a cover and bed of a harder nature. Again, in complexion, and thus in admixture, also in nature, namely, ground-mixtion, appears a difference of the stone layers ; as quarry-stone, sand-stone, lime-stone, &c. may well lie interchangeably together : and not only in these large *strata* of earth and stone,

stone, which take up a large compass, but also in peculiar small seams and veins, traversing such large *strata*, often various layers are observable.

Of this miniature *flat-work* stone, if I may so call it, we have an extraordinary instance, at Friberg, in the uncommon jasper, or coral stone. For, there we have (1.) a white, heavy spad. Under this (2.) a smooth mountain-crystal, both of them from 1 to 2 inches thick. (3.) Amethyst. (4.) Again, mountain-crystal, or *quartz*. (5.) Jasper. (6.) Mountain-crystal. (7.) Jasper. (8.) Mountain-crystal. (9.) Jasper. (10.) Crystal. The former eight layers are often only the thickness of a fine thread, and all together scarce exceeding $\frac{1}{4}$ inch, and yet very distinct. (11.) Jasper, of a bright red. (12.) Jasper, of a dark red. (13.) Chalcedon. (14.) Jasper. (15.) Chalcedon; nay, the two last, once or twice more, alternately. (16.) A firm horny quartz. The last six or eight grow still thicker and thicker, the jasper there being often an inch thick, and above. These layers of precious stone, which are extremely beautiful to the eye, cohere very firm and close together, so that the entire stone bears splitting transversely, better than in the seams; and then they lie not so flat in shivers on each other, but vaulted one over the other, with small arches, so that the thickest layer of jasper may be clearly seen to traverse most of the upper layers, till, at length, it gradually loses itself: yet there the jasper-layers are most easily separable where thickest, also where the chalcedon is thickest: and as it there exhibits pure round eminences, standing close to each other, like so many little balls cut asunder, whose concavities lodge in the chalcedon, it is here, at Friberg, commonly called *coral-stone*. In particular, the violet cast of the amethyst, and the red blush of the jasper, whereby it comes to resemble coral,

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would seem to suggest an enquiry, whether their tint be not owing to the share of metal they contain. I know not, whether the amethyst does not hold gold; as there is no experiment extant for giving such a violet colour to a stone, or stony glass-flux, except by the means of gold, with the addition of tin; especially, as I have a method of imparting this colour lastingly to spring-water, without making it less sweet and potable, from gold, without tin, or any other mineral, or metallic body, barely by means of a certain salt. As to the jasper blush, I would mention iron, as, at least, the earth of this metal eminently carries this colour; or even gold, either separately, or jointly, with the former, none of these circumstances being inconsistent with the nature of things. All this I propose as conjecture only; for tho', indeed, neither gold, nor any other metal, is, by analysis, or resolution, educible from such amethysts, *quartz*, and *druse*; nay, is as little possible, as that the least trace of a metal should be manifested by the quickest, most tender scales, in artificial, variegated fluxes and glasses, from the metal being widely dispersed; and to be educed from glass, a body the most tender and retentive, and to be exhibited in its metallic form: yet, *synthesis*, or composition, gives some countenance to the conjecture; namely, as the well known gold-purple, or the gold powder, made with tin, bears being introduced as a violet colour into glass, nay, into a common water: this I rather mention, seeing in chemistry, and according to the doctrine of nature, the proofs from composition are preferable to those from resolution. But be this as it will, the different *strata* in this jasper-stone manifest something different, if not in the ground-mixtions, yet in the degrees of the coction and maturation of the mixts; the *strata* not being produced externally in couches,

couches, in the same manner that floods may be supposed, from time to time, to accumulate different layers of earth, sand, &c. on each other, but spontaneously, from a vast number of earthy particles, in the way of a precipitation, both by means of the subterraneous instruments of maturation, and those of the moist, warm air, this stone striking out quite to the day.

For, there is no one *squat*, where a flood, the most partial imaginable, can be exhibited as a cause; but dipping into the *deep*, and stretching, as it does, into the *field*, it is over-laid with the abovementioned variegated stone; in respect of which it may rather be called a vein: and accordingly it takes its rise from the bowels of the earth, and, probably, in the way of an exudation, or fermentation; at the close of which, the refuse, like dregs, separates upwards and downwards, the noblest parts remaining in the middle.

Yet, not to digress too far, we must here distinguish between those *squats*, once really formed by the waters of the deluge, and those spontaneously and gradually produced before or after it, barely by length of time. The former are either unchanged earths and sands, or become firm, and thus turned to stone, as the shiver and sand-stone, chiefly here at Friburg. The latter are partly the harder and closer sort of stone, as *gemfs*, *knauer*, and all those banks, or shelves, chiefly coinciding with the deeper under-lying stone; partly fermented, or exudated, petrified, mineral juices. Of the second sort, being, at present, foreign to our purpose, we shall treat hereafter. As to the first, we shall now offer some answer to the question started above; namely, why, in the *deluge-squats*, we commonly find the *pyrites*, and, more frequently, the *copper-pyrites*. Tho' this question may seem somewhat premature, consider-

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ing the small depth of earth we have hitherto had, occasion to lay open; our experience, however, reaches thus far; that what lodges in shiver, is *pyrites*, and that at all times. We here speak of capital *squat-works* as of veins, over-looking, as of no account, the inter-current small fibres of *glitter*, and small interspersed eyes of ore: for, where was there ever a *shiver-squat* of *glitter* laid bare, where this last was the essential, constituent part, and the *pyrites*, either not at all, or only incidentally in it, as, we know, is the case of veins dipping extremely deep? or where did we ever hear of noble veins of *red* and *white goldish* ore, *cobald*, *bismuth*, *glassy* ore, and the like, in shiver-mines, unless in transverse yeins?

Pyrites chiefly consists of iron and sulphur; now we find shiver exactly to correspond in these two constituent parts of the *pyrites*, if not essentially containing them. Above all kinds of stone, it contains sulphur, nay, often that alone; as plainly appears in *alum-shiver*, *stone-coal-shiver*, and the like black bituminous bodies. To the formation of iron all fat earths are adapted, nay, all earths, so they be capable of being duly combined with the *pblogiston*. Iron is the most universal metal, as I have repeatedly shewn already; is the primordial metallic form, producible the most readily and easily from an earth: iron comes nearest the nature of the inflammable earth, as appears from its deflagration with salt-petre. Sulphur and iron are the two capital, middle mineral, and metal-species, as undeniably appears from all considerations, whether œconomical, medicinal, and purely natural; that were we to suppose any one metal or mineral produced express, these two may, above all other ores and metals, be affirmed to be so. Again, what is *copper-pyrites* in ground-mixion, but *iron-pyrites*? and tho', on the score of the

the excess of the copper, which may sometimes amount to almost half the ore, it usually quite loses the appellation, *iron-pyrites*, yet, the quantity of copper with the iron is inconstant and variable: for, *iron-pyrites* may well be without any copper, as those of Hesse, Boll, Altsattel, Toplitz, &c. sufficiently shew, but *copper-pyrites* never without iron. And should this be allowed of no weight, yet what has a greater affinity with iron than copper? We have often *copper-pyrites* veins, without the least *lead-glitter*, much less any other ore, either attending or intermixed: but where is there any other mine, without a number of different veins, either accompanying or intermixed, and without any *pyrites* at all? Iron and copper cohere so firmly together, as often to be scarce separable, as the Strasburg undertakers experience to their cost, at the Lower Hartz, where there lie some hundred quintals of metal, as 'tis called, or black copper, holding 56 lb. of *rose-copper* the quintal, and 4 loths * of silver: nor can they, with much more facility, separate the grey iron-stone (containing 30 lb. of iron the quintal, and tainting the copper) from the copper-ore. Copper, next to iron, above all the metals (if we exclude zink, bis-muth, and regulus of antimony, and perhaps also tin, as belonging to the class of semi-metals) manifests the largest share of *phlogiston*; not to mention other circumstances, too tedious here to enumerate.

The question may be resolved by proposing another, namely, why in other ore-matrixes, as for instance, sand-stone, loam, and the like, which, equally with shiver, are derived from the deluge, there are not also *pyrites-squats*. To this the answer may be, that all such queries are premature, and ought to be forborn, 'till we can assert, they

* A loth is half an ounce.

have been duly sunk, or dug for, without finding any thing of that sort. In the famous sand-stone quarry, at Pirna, in Misnia, the common ore-depth has not been hitherto reached; and what pity is it, that so extraordinary a quarry should not be more carefully examined? The loam-beds, likewise, have equally partaken of the same fate; namely, to lie neglected and unexamined.

Now, tho' our experience, which is, hitherto, inconsiderable enough, should suffice to give the preference to the *shiver*, above other *stream-beds*, in regard to the *pyrites-squats*, yet it would be no difficult matter to find out some reason for this difference; namely, those parts proper for the mixtion of *pyrites*, as the fat earth for the sulphur, and the tender earth for the iron, as has been already mentioned, are found, especially the first in the *shiver*, not only proximately prepared for the *pyrites*, but also indisputably in greater plenty than in loam and sand: and the matrix is not to be considered as a bare receptacle, but as a receptacle of proper materials too; that is, the inhalations, or impregnations, called *inweatherings*, cannot alone have their effect, nor their supplying their materials produce an ore, unless the matrix hold, and reciprocally furnish also, by means of an exhalation, called *outweathering*, its proper matter; that the passive may, by means of the agent, come into motion, to form the third body here intended. In loam, 'tis true, a fat earth is contained, from which iron may be, and actually is produced; but naturally not in such quantity, as that the iron should put on the form of a *pyrites*, and it is the same with a body over-dosed with sulphur. In the sand-stone the parts of the whole have too far deviated from the nature of an earth, and arrived at such a degree of hardness, to be incapable of a greater remove from the form of an earth, from which

which orey and metallic particles are to take their rise: for, this stone consists of pure sand-grains, which are so many small flints, and, consequently, the densest corpuscles; and like so many hardened, indurated matrixes, where the effete materials are, even by the strongest influx, with difficulty brought to motion and conception. Yet here some might consider, as opposite to this, the commonly flinty and quartzy, nay, horn-stony rock of the *selvages*, which, in veins, form the case for the ore. But, not to mention that objects lying near are not always to be supposed derivable from each other, tho' they may successively, or even simultaneously, happen to exist; the principal reflexion and query here may be, whether such quartzy and horn-stoney rock was already become such a dense and close body, when the ore began first to be lodged there? or whether it was not of a moister, softer, and a more receivable texture, wherein the mineralising *weathering*, or damps, might find lodgement, incorporate itself, and thus the tender vessels of the matrix, namely, the tender *selvage*, emit some material efflux for the production of the ore? The first opinion fails, for this reason; as it must be allowed, that this stubbornness in the earth was not original, but adventurous; and that something flinty, quartzy, sandy, stoney, glass-yieldy, or, in a word, Becher's first earth, might not exist in metals.

And in those productions of the *pyrites*, for which the deluge has laid the foundation, something peculiar is still to be observed: namely, that *pyrites* is even found weathered on bodies at a great remove from the mineral kingdom, and unadapted for it, as wood; of which I have both seen and read instances. M. Lichtwer of Dresden, Inspector of his Majesty's cabinet of minerals, has a small piece of wood, on which a glittery,

terry, mock-leady matter was not only manifestly weathered, but lodged in its rents. This sample, which was found in 1658 in an old mine at Schwartz in Tyrol, manifestly shews, it was not only a real unpetrified wood, but also the ore so closely adhering to it, as to exclude the least suspicion of a cheat or imposture. And this has led me to enquire farther after such samples; at least, whether ore may not sometimes have been found on bodies, tho' of an extraneous kingdom, yet approaching nearer the nature of stone than wood does; as for instance, on periwinkles, muscles and the like shells, unchanged, unpetrified; though that such parts are also petrified is evident from the fossils of Boll in the territory of Wirtemberg. And I have seen the muscle-work of Wicrau in Osterland, on the Orla, a mile from Neustadt, stuffed with sand-stone, in which lead-glitter was implanted deep into the shell, but still distinguishable and separable from the adhering sand-stone; tho' I considered it rather in a petrified than in a native or animal state. But we experience this still more in wood petrified, or reduced at least to stone-coal; M. Mylius, among others, insists upon having seen samples of that kind, filled with marcasite, from the Fischbach in the territory of Henneberg; and pieces of wood, reduced to marcasite, have been found at Leipsick and Bitterfeld, in digging for wells*. Yet such instances, where pieces of shell or wood are become real stone, are immaterial, however extraordinary, in other respects, it might be to find lead-ore, near such fossils, as it would be no less so to find lead-ore in sand-stone. And tho' there were no samples of the pyrites, or any other ore to be shewn on the unchanged remains of the deluge, yet such might not come to the day; of which the above sample of wood, overlaid

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with

* Saxon subterr. P. I. p 62.

with glitter, appearing but very lately, is a plain instance; and as experience shews, that many things carried off and buried by the deluge have retained the nature of their respective kingdoms undestroyed: tho' the bodies of vegetables, in particular, are of so watry and changeable a mixtion and texture as to be incapable of any length of duration, they turning either to earth and ash or stone, and thus either degenerating or improving; yet in many places they have preserved themselves from corruption: and bones and shells have undergone a kind of calcination, and wood a hard exsiccation. I have, however, had samples, clearly exhibiting parts of animals, in their unpetrified form and mixtion, suffering *pyrites* to grow upon them, and thus rendered susceptible of the action of a mineral weathering or damp; nay even more so than in vegetables.

Tho' we might well postpone this article to the following paragraph, where it will appear, how the *pyrites*, without any action of a deluge, may be supposed to be generated barely by length of time, and is so at present, to say nothing of entire large veins; tho' there is a great deal of room to think, that all of them are not absolutely referable to the creation, as to their origin, but that here and there, amidst the never-ceasing, violent working of the huge mass, there must needs have happened large wastings of ores, and springing or splitting asunder of whole rocks, and that these still happening, may be attended with new productions, in order to the filling up these rents or gaps: yet having already real testimonies enough to verify the opinion of the new production of ore, it would be needless to call possibilities in aid. In the first place, sinter is found with its glitter and *pyrites* upon it, not only in some old mines at Friberg, but also in various places, in caves, and even

at the *day*: by sinter is meant, in the full extent of the word, all those earths in the *groove*, which, by means of the gentle motion of the waters, work out and exude from the fissures (whence they are called *gur* *) and thus accumulate; turning thick and smeary, a part hardening to stone, and forming icicles, a part remaining earthy and soft like butter, according to the difference of times, place, the nature of the earth itself, and other circumstances. The last sort consists commonly of an ochry, yellow and brown substance, and doubtless is only the metallic earths of *pyrites*, somewhere or other weathered, or dissolved; its earth, by that destruction, becoming highly tender and light, settles downwards on fissures, thro' the water, and also mounts upwards, in its tenderest parts of all, to the *day*, as is known to be the case of most medicinal springs. The first sort is more of a calcarious or spathy white, not so common, and probably derived from some such rock, which, if not a pure lime or gypsum stone, yet partakes of it; at least, quartz or the like, it cannot be: this we see from its resolution, particularly by its ignition and extinction; where, by the lixivious odour, by the crumbling and extraordinary degree of whiteness, it bewrays its origin: again, from its composition, when the waters in vaults, and adjoining to walls, (whereof, among others, the great aquæduct, called *halserbrucke*, near Fribourg, is a plain testimony) let fall again the lime, unobservedly conveyed along with them, and re-apply it to the roofs and sides, in flakes and icicles; yet with this difference, that such a sinter, as at the *day* even in places, that seem pretty close, and yet not altogether so, as quite to exclude the air, arrives not to that degree of firmness and hardness, like what such a one has, that proceeds from

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* From the German *gieren*, signifying to ferment.

grooves quite run to decay, or not immediately exposed to the fanning of the air.

Moreover, we are to observe this circumstance, which gives a great degree of probability to our notion of both these sorts of sinter, *viz.* that the white, like a lime, binds as easily as stone, which the yellow, being metallic, does not: yet it should be remembered, that we are to except the luty or talky *sinter* or *gurs*; such as, in particular, are to be met with, very beautiful, on the Himmelsfirsten and Gunther, at Weissenborn; but which is not so much of a lime, as a grey-silver white, and does not petrify. In short, the *sinter* is either luty, and of a marl-earth; or metallic, chiefly from iron; or calcarious and petrefiable. Of the third sort, namely, that frequently called *stalactites*, or *stalagmites*, drop-stone, and which must be well known from the famous Bauman's cave, is not so uncommon in mines, provided we are attentive enough: yet, so far as I remember, it is no where found, in the territory of Friberg, so plentifully as at the mine called Himmel-farth-christi; nor, indeed, can it be so common, seeing, in the first place, old decayed mine-works, and moreover, certain waters, must concur to its production; and *there*, upon due observation of only the nature of the *sinter*, the most pertinacious in opinion must drop the period of the creation for its first origination; for, *there* the fissures, the sides, and roofs, are covered over with a stony shell, or crust: nay, what is very extraordinary, the water in a pit of the groove, when full, was covered over with a stony crust, as with a thin ice, the thickness of the back of a knife, and tho' loosened at the sides, still remained floating upon the water, whence it was called *floating sinter*.

On such drop-stone actual *lead-glitter* has been found, two samples of which I have in my own possession;

possession; and many other instances I have observed of the production of ores and *pyrites*, even lately: as, a *sinter* from the territory of Hohenbircke, from the greatest depth hitherto reached, exactly overlaying a *drusy* lead glitter, and the latter, a *sinter*, and this *sinter*, *lead-glitter*, as so many pebbles, or buttons, artfully accreted to each other. I am possessed of a *sinter*, whereon the *pyrites* is visible, and in particular, the coppery; nor do I doubt but many more such instances may be hereafter met with, when application is made to these subjects, with more accuracy and attention; — so that *sinter* is still at this day produced in places where before there was none.

It may seem needless to mention particular instances of this kind, seeing earth is known to be derived from water, and stone from earth. Examples of waters yielding stone are very numerous. The Caroline waters at the Prudel deposite a whitish, intermixed with a flesh-coloured, and throw up a yellowish stone, firm enough to bear working and polishing, like marble; and that in such plenty, that the inhabitants are, at times, obliged, not without great labour, to remove it, to prevent its choaking up the spring. At Metzana, in the County of Schonberg in Misnia, there is a stone-quarry, where we have a plain instance of the same sort: the stone is done over as with so many crusts of ice, and directly beneath the under-turf earth huge masses of *sinter* are dug up. *Sinter* continues growing so long as that sort of earth, whereof it consists, is conveyed to it by the waters, and the free access of the waters not interrupted by the entire concretion of the fissure, or by other accident. The first is evident from all the abovementioned instances; in particular, the Caroline stone, which may be daily observed

accreting more and more according to the things laid therein; also to fissures and cavities, which often become gradually narrower, and, at length, are entirely blocked up. The second is also very plain, as an increase always implies a free access; and, as evidently appears, among other things, in mixt-works, such as I above instanced in from the Hohenbirck groove, where we see, that where the ore and glitter, forming *weather* or damps, have, as it were, ceased, the stone-forming, or petrifying waters, begin to overlay the *glitter* with a crust of *sinter*; and this again ceasing, the *sinter* to afford a couch to the *glitter*.

Here I must not omit mentioning, that this stone forms no layers or shelves, tho' its accumulation be by a shoving of earthy particles precipitated out of the waters, over each the other; whence it separates, not in flakes or leaves horizontally, but rather upwards and downwards; also, in breaking, it manifests a texture, shewing its increase to happen sideways, by an apposition of tender threads, almost in the manner of the Hungarian *atlas-vitriol*. For, from the *sinter* from walls, and thus from lime already prepared, which easily bears being divided into flakes, we cannot conclude to that which is derived from crude lime-stone, and other unknown admixtures. My reason for mentioning this, is to obviate some mistaken notions about the Caroline white coloured stone-strata, which are evidently distinguishable from each other, not only by the colour, as being beautifully striped like a piece of cloth, or fillet, but also by their easy separation at the coloured parts: and, doubtless, the different colours should afford something different in their internal *mixtion*, at least in the proportion of it, upon making a due proof of some of the principal strata, each apart.

On this *sinter* then, thus lately formed, and still forming, even to this day, we find *glitter*, iron and copper *pyrites*, not conveyed by streams of water, nor agglutinated, but *weathered* thereon, or produced by *weather* or damps. This I affirm, to obviate a doubt the reader might otherwise entertain, from pieces and bits of ore being loosened either spontaneously, or by men's hands, from veins, and conveyed along by the waters, coming somewhere or other to lodge and fix, and to be concreted, not only by petrifying waters, but also by binding *weather*, or damps: and I have had samples, where such concretions, by waters, of pieces of stone or rock, was very visible: nor is it any new thing for the damps of ores and stone to fill up again the rents and chaps in *vein-stone*. The ore on *sinter* is a plain and easy proof in behalf of a *weathering*, or a production by damps, rather than by way of *streaming*; for, (1.) both the *glitter* and the *pyrites* appear in as compleat, cubical, and angular figures, as they do on quartzy and spathy *druse*, where few will readily admit the effects of a *streaming*, and as little doubt of those by damps, as shall be shown lower down. (2.) I never once met with any one piece of ore, either on *druse* or *sinter*, tho' I have accurately examined a great many samples, where the piece in question manifested any flaw; all of them, even the smallest bits, having their proper smooth surfaces and sides, as the most indisputed original *mixtwork* could possibly have. (3.) There must needs interpose a manifest band or cement, either proceeding from the mutual action of the bodies themselves, or from an external *weathering*, or from water, to bind them together; and yet, between the *sinter* and the ore no such third body is observable to form the band or cement, the ore lying immediately pressed in upon the stone.

In short, the *pyrites* of such places is a new production; and its foundation being but lately laid, how can the superstructure be supposed to be of an older date? The *sinter* manifestly is produced as it were before our eyes, and shall the ore then, found thereon, be made coeval with the world? *Sinters* claim our special regard; and, without vanity, I may affirm, that, as far as I know, no one, before myself, hath ever made the observation of ores growing on them.

This leads us to consider, whether ore may not be found successively generated in *druse*, in nests and fissures, rather than on *sinter*: as, (1.) such matrixes are more adapted for the conception of ore, from their flinty, quartzy, and consequently more appropriated nature, than calcarious, spathy *sinter-stone*: besides, that the *ore-weatherings*, or damps, lie more undisturbed in such close matrixes, than where the *gur* is in motion. (2.) As there are not wanting *sinters* in *druse*, whereon, again, ore accretes. (3.) Should we only consider, why those *druse* exhibit, if not always, yet commonly, and very plentifully, their ore, which is, for the most part, *pyrites*, on one side only; must we not thence conclude, that what thus adheres to the *druse*, did not at the same time arise with, or spring from it? Again, that matters, thus brought together, may have had their origin and flux from that side whereon they are found; and, lastly, that they were applied thereon by *weatherings* or damps? And can we imagine productions, of which often two, three, or more species are found lying on each other, to spring, either altogether, or instantaneously?

From the most unexceptionable experience, we learn the clearest and purest waters to hold and carry along with them earth; afterwards, to let it fall; further, this earth to turn to stone; lastly, and

principally, these stones to prove as crystalline and transparent as the clear tacks or spikes on *druse*; as appears from the following experiment. Take the fresh urine of a boy, leave it to stand for three or four years in a staunch, large cucurbit, about half full, covered over with a bladder, on a shelf, in a room of so temperate a warmth, that scarce any thing shall evaporate (tho' it be impossible but some should) but only amidst tender mounting steams, trickling down again in drops, the least distinguishable separation, that can be procured. Now, after hitting on the proportion of the vessel, and the due degree of warmth, there will accordingly be observed, sooner or later, after the precipitation of the very gross, tartareous, earthy particles from this water, above on the rim of the glass, small, white, oblong stones, of the length and size of oat-grits, adhering so firmly to the glass, as to remain undisturbed upon decanting off the urine. The first time I came to observe them, I could have averred them to be a crystallized salt; but, upon rinsing them carefully out, they evinced nothing saline on the tongue; nor, according to the known quality of salt, did they admit a solution in the hottest water, so that they must be pure crystalline pebbles, oblong and prismatical, like nitre; figures that the quartzy tacks on *druse* exhibit mostly, and of which I procured a drachm from six lb. of urine. This stoney matter, which may properly be deemed Becker's first earth, appears also in the actual salt of urine, when melted to a glass. And here we see how excellently, and how far, long digestion, nay, even only time and patience, avail in producing forms and effects, generally deemed impossible, and seldom looked for in laboratories, except in those of nature; whence such stoney matter should be generated in human bodies, is not difficult to be accounted for, when

when we consider the seeds of it may be conveyed along with the water we use.

'Tis true, a very small matter of the tender essential salt of urine is incorporated in these small stones, as may be easily observed by its volatility, and extraordinary agreeable smell, upon ignition; yet so incorporated, nay, fixed as it were, that neither the taste can perceive, nor hot boiling water extract any of it. Moreover, it is impossible to exhibit either a saline, or other water, whether natural or artificial, containing earth, that ever yielded the like crystals; all the vitriolic, aluminous, nitrous, &c. waters, always shooting into their own proper saline crystals, be the time appropriated for that purpose never so long; yet, with this remarkable difference, that the longer time they take to shoot, the crystals prove much larger, harder, more durable, and so far approach nearer to the nature of stone; but, in a pure, insipid, earthy water, tho' standing never so long, no experiment to this purpose is extant; and indeed, from waters entirely devoid of salt, no such thing is to be expected, as they want the requisite cement, or interposing substance.

The shiver-mines of Ilmenau in Franconia, afford those well known bodies, called *kidneys*, of an oblong oval figure, and enclosed in shiver, as in a shell. In these we often find, together with the figures of fish, figured cavities, often containing a clear water, bearing the impressions of ears of corn, spray of the pine-tree, or rather, a kind of coral, the circumference of which is set round with small, transparent, white stones, like sugar-candy; and tho' these stones may be easily crushed under the teeth, yet, in the fire they lose nothing of their hardness or transparency. Now 'tis impossible to imagine these small stones were originally created, the circumstance of the water contained in the cavities

vities probably suggesting their having shot from that water, like a salt.

Nor will it seem unnatural to view in the same light the *druse*, or those cavities candied over with crystals and variegated stones, tho' we could not by art imitate their beauty, size, and firmness, for want of the proper means and opportunities for that purpose. It may be presumed that the earth was, at first, a soft, yielding, spongey body; that, by the gradual separation and evaporation of the superfluous moisture, it became more and more indurated and exsiccated; that by this means, the earth, in particular the firm rock, came, by violent shocks, or earthquakes, to acquire rents and fissures; that in these, the several sorts of waters happened to lodge; that these waters contain earth; this earth turns to transparent stone; all which propositions are easily deducible from what has been already said: at least, no one, rightly considering the proper crude ground-bed of these *drusy* stones, can find any better method of accounting for their origin: that they should spring up from it like a mushroom, the bare inspection is sufficient to disprove; as no cohesion or connection appears between them, only an external application; and this so very evidently, that the *drusy* stone lies quite loose and naked in its nest or bed, consequently, without manifesting any thing like a root, or with its stem, which is mostly a quartz or flint adhering to it, easily separable from the crude rock underneath, in which no root is observed to run and lose itself: neither can these unsaline crystals be supposed to proceed from pure damps or *weatherings*, for the weatherings that produce any thing in fissures, move laterally, as may be seen in ores on *druse*; whereas the stones in question stand up and down, like a set of teeth in a jaw-bone; nay,

nay, sometimes with pieces in them like *water-nuts*, which scarce cohere in one single point, often not at all. Upon the whole, all circumstances agree, that neither an *exhalation* nor *inhalation*, but a crystallisation from waters, like the shooting of salts or sugar, is the genuine, if not the only cause of mountain-crystals, and the like transparent, variegated stones. I shall say nothing of their figures, which, like common salt, are either cubical; or like nitre, prismatical; or like *tartarus vitriolatus*, of irregular angles, and unequal sides, commonly hexagonal: nor mention, that an unsaline crystal earth, tho' not in such plenty as a saline, is yet as intimately mixed in the water, nay, in the fullest degree of clearness, passes through the closest strainers; consequently, the crystallisation of salt is here not improperly alledged for a model, or pattern. In short, the *pyrites* is a thing that has grown, still grows at this day, and will continue to grow on *druse*, so long as the interior parts of this mass of earth are subject to those motions and dissolutions they hitherto have undergone. Here 'tis worth remarking, that the *pyrites* generally possess the eminences of the *druse*, and often their outmost tacks or teeth, and that only with one of their angles touching in the fewest points possible, and not lying, but standing thereon; shewing that they were not there produced, but conveyed thither from some other quarter.

I have had many samples of *mixt-work*, with rents and breaks in the rock; the former filled up with, and the latter joined together again by *pyrites*. Some *druse*, or quartz, manifest such cracks and apertures, as plainly shew they were formerly entire, and afterwards burst or sprung asunder; and in these fissures the *pyrites* has been found *in-weathered*, or lodged: so that I know not whether

it be so very necessary to trace such fissures as high as the creation, and not rather suppose them of a much later date. Moreover, I have had pieces very clearly shewing that they were broke off, and again joined together by a *pyrites-weathering*, or damp, forming one entire mass; nay, in part, crusted over with *pyrites*; but this cannot be reckoned anything new, or uncommon.

What is worth enquiry is, how *pyrites* can get into close solid rock, as a *knauer*; as miners, after masons and quarry-men, call a sort of quarry-stone, found with us, and generally elsewhere, directly beneath the under-turf earth; consisting of very small, nay, scarce distinguishable seams, and two sorts of stone; one, a grey, sparkling, scaly sort, or a *glimmer*; the other, a white, quartzy sort, constantly interchanged with the former, and both closely joined together.

In this *knauer* small eyes of *pyrites* lie, and that on the finest fissures, but not discoverable before the stone is parted asunder, and then most certainly, the *pyrites* often appearing rusty; consequently, a *weathering*, or a *watering* producible of rust, must have found access thither. These eyes are also here and there singly interspersed in the most entire and firm rock, without the least signs of any destruction or dissolution. Whether the first be shoots or capillary veins from larger branches, I shall not pretend to determine, but the second are something peculiar: they cannot be considered as small *shoads*, as the *knauer* itself is not such, but a rocky, wild stone, constituting an original part of the creation; consequently, such eyes must have been produced in its soft, juicy, and yielding state, before the matrix was become perfectly hard, and unfitted for conception, in which case, the impregnating damps and mineral juices could have no access.

We are next to examine those periwinkle and muscle shells, either quite penetrated, or crusted over by the *pyrites*; and some of these shells have their whole cavity lined therewith, as the *belemnites*; others, together with the *pyrites*, hold a selenitical matter, or gypsum-stone; again, in others, the shell is entirely *pyrites*; again, the *pyrites* is externally *weathered* on the periwinkle or muscle figure, which is commonly a marl, or gypsum-stone, sometimes at one, sometimes at the other end, and sometimes all over it; and, which is the rarest case, the shell still remaining, the *pyrites* lies immediately either on, under, or between the shell. Now though periwinkles and muscles are in such quantities in nature, the number thus petrified is hitherto found inconsiderable; but the samples I have either in my own possession, or have seen, or been told of, are mostly *cornua ammonis*, *tellinæ*, *chamæ*, *astroitæ*, *belemnitæ*, *turbines*, *peetinitæ*, *fungitæ*, *alveolus*, *Luidii*, &c. Though 'tis not to be doubted, but time may discover more sorts; nay, that the same may be presumed of all such as lie in earths, where nature finds materials, opportunity, juices, free access, and the like circumstances, as grounds and foundations for a *pyritification*; for, both muscle and periwinkle works are all, in the ground of their earthly mixtion, one and the same, namely, already such in nature as that, among all the parts of animals, nothing comes nearer to the stones of the mineral kingdom, especially the calcarious sort; consequently that they are fitted, almost in their native slate, or at least without any peculiar tedious preparation, barely by means of a slender exsiccation, both for a proper petrification, and the conception of ore, is not repugnant to my hypothesis. And thus it depends on the abovementioned circumstances, that such shells are, at some times, now found changed;

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at others, not at all; also, that the shells either continue to subsist, or are entirely consumed; and lastly, that generally they have no *pyrites* in or about them: as, among others, we have an instance in the sand-stone, wherein I have, with difficulty, found such *pyritified*. From a due consideration of all the circumstances evident in this subterraneous muscle history, we cannot suppose these bodies to be the effects of a *lusus naturæ*, or even to be of a subterraneous origination.

And should it be objected to my making the productions, namely, the volatile salts and foetid oils, procurable in the fire from such fossil, figured wood, muscles, and bones, certain indications of their vegetable and animal original, that these salts and oils are already contained in the earth, in particular, that common salt is extremely fitted for volatilization; that, probably, the sal-ammoniac at Puzzuolo in Italy, and the like places, where the bituminous sea-water, or even sal-gem, is, together with *pyrites* and stone-coal, made to act in a due manner in the bowels of vulcano's; and the petrols, which stand proximately allied to amber and stone-coal, greatly resemble our oils, burnt out of the fatty, resinous parts of plants; that from *asphaltum*, black and yellow amber, from aluminous, stone-coaly, black, fatty, shivery minerals, not only such oils, but, in part, also volatile salts may be prepared; yet it does not therefore follow, that the origin of these things in question, though they manifest themselves in, is immediately from the mineral kingdom. In a mediate sense indeed, according to which every thing in nature is in a constant rotation and flux, we must allow, not these matters only, but also the entire vegetable and animal kingdoms, to be derived from the earth, and thence from the widely extended mineral kingdom.

Now,

Now in and upon these matters, dug out of the earth, all kinds of *pyrites* are often very evidently seen ; tho' not so frequently on bones, at least so far as my experience reaches ; a thing not to be wondered at, seeing they are not so common as periwinkle and muscle shells are ; the same also holds good of wood, which is not so well adapted for mineralisation. To conclude the busines of the generation of the *pyrites*, and of ores in general : they are not all of them to be ascribed to the first day of the creation ; consequently, nothing hinders their being still produced at this day.

I have still to add, that the generation of ores appears in some measure to me in the same light, as that of vegetables and animals. In some measure, I say : For (1.) ores shed no formal seeds, from which, with the concurrence of a proper matrix, ore is again produced. (2.) Ores, according to their internal mixtion, have no fixed period of duration, but remain for ever unchanged, if not exposed to external violence, partly, on account of their peculiar unchangeable manner of mixtion ; partly, their bedding, from which the air and warmth those grand instruments of destruction are excluded. Whereas vegetables and animals have their destined periods, tho' stretched out ever so long, from the tenderness of their mixtion and texture : but so far only I make the resemblance to hold, as in the vegetable and mineral kingdoms, some die, and others again revive.



C H A P. VI.

Of the IRON in the PYRITES.

IN the foregoing chapter having treated not so much of the material origination, as rather, if not principally, of the time of the production, and consequently of the creation and generation of the *pyrites*, I should now immediately proceed to its material principles: but this, at present, is neither adviseable nor possible, tho' a method of writing that most are fond of: seeing we must first consider *pyrites*, as analysed into its proximate parts, and thus meditately proceed to its principles: and we can as little pretend to begin our research as description there, where nature has begun her work; there being difficulty enough to discover such principles, as I will not say, ought to be made objects of our senses, a thing neither possible nor reasonable to acquire, but by probable conclusions only, fairly flowing from observations.

There is the same difference between the constituent parts and the original principles of a natural body, as between proximate and remote; *pyrites* are derived from water and earth, as their principles, or remote parts; but consist of the following *mixts*; viz. the fat earth, or sulphur; the mercurial earth, or arsenic; the metallic earth, or iron, as their proximate parts. Some instances there are, in which *analysis* stands verified by *Synthesis*; others, in which it does not. Cinnabar not only consists of quicksilver, as its separation plainly shews, but may again be formed from

sulphur and quicksilver, and that most easily and constantly ; and there may speedily, though not constantly, be prepared a formal antimony from regulus and sulphur : But in compounding sulphur and iron, the parts into which a pure *iron-pyrites* is evidently resoluble, it does not succeed. The reason of this difference is, in the first place, to be sought for in the metallic earth of *iron*, which is highly coarse and fixed, nay the crudest of all, and proximately derived from the universal unprepared earth itself, and consequently not so combinable with the tender, volatile, elaborated, mercurial, reguline earths. 2dly, The sulphur, which is something highly tender, volatile, and dissipable, flies off and is destroyed, before ever the *iron* can, by ignition, be brought to conception ; or the *iron* comes to be unfit for the purpose, by losing its metallic form, and turning to a rust, in which the sulphur cannot find a due ingress to coalesce with it. And hence it is, the sulphur is so superficially combined with the *iron* in the pure *iron-pyrites*, that without any force or violence, such as cinnabar and antimony require to separate out of it, barely by the external heat, nay, by the bare access of the air, without fire at all, it may be made to operate on its accompanying *iron* : which is the formal reason of the crumbling and vitriolisation of the *pyrites*. It, however, from hence and other instances appears, that the rule, implying the necessity of proving *analysis* by *synthesis*, among ores and decompounds, such as ores commonly are, ought not to be looked upon as universal ; some bodies evidently bearing *analysis*, but with difficulty, if at all, *synthesis* ; for instance, the *pyrites* ; others again easily bearing composition, but difficultly, or not at all, resolution ; as the neutral salts.

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We shall, in the first place, enquire into the constituent parts, then into the principles of the *pyrites*: the former we shall consider in this and the following chapters; the latter, namely the principles, in a chapter apart.

In order to treat with propriety of the constituent parts of the *pyrites*, we must premise its division into *sulphur* and *arsenic-pyrites*. By the former I understand not only that sort which yields sulphur and pure *iron*, with little or no copper or arsenic, consequently little or no sandarach: but also *copper-pyrites*, nay, rich copper-ores; by the latter, that white sort, which contains pure arsenic with but very little *iron*, copper, or other metal, and with little or no sulphur; the arsenic being in form either of a grey meal, or a footy arsenical sublimate or *fly-stone*, and giving, by means of a proper addition of sulphur, sandarach; this kind of *pyrites* is at Friberg called *misspickel*, but in the Obergeburge, *poison-pyrites*.

In short, the former are either more, or entirely sulphureous; the latter more or entirely arsenical. Now in the sulphureous, the *iron* is the principal and largest part, and of which they all indeed consist; copper holds the second rank, which in some is none at all, in others in a small, in others again in a very rich proportion; sulphur, the third, and which like the *iron*, is in all the kinds of the *pyrites*; arsenic, the fourth, of which in many there is none, in some only a very small proportion, in others a considerable one, bewraying itself either in the *sulphur-slags*, or in the sandarach; but contained in no one *pyrites*, where *iron* and sulphur constitute the capital parts, so largely, as without the addition of *misspickel* to the

sulphur slags, to be worked for sandarach, so as to quit the trouble. In the arsenical sort, a stoney iron-earth is the principal and largest portion; and what is called the *fly-stone*, the second and last; with the observation, that whereas the sulphur in the first sort makes a fourth in respect of the iron; here at Friberg the arsenic in the *mispickel* commonly makes a third; and at the Obergeburge, often a full half, in respect of the remaining irony, quartzy matter. Nay, the abovementioned black, arsenical, fossile matter, otherwise to be found near *red-goldish* ore, but particularly pure, without the like accompanying rich silver-vein, in a mine near Schwartzenberg, and there also called *poison-pyrites*, also *testaceous cobald*, contains neither iron, nor any other earth, but in the fire sublimes in its entire substance, and thus proves a pure arsenic, or fossile *fly-stone*. But here the name is misapplied, if we abide by the definition of *pyrites*, namely, its being an ore, consisting either in a sulphurated or arsenicated metallic earth; whereas this, on the contrary, can shew nothing, either of a metallic, or other earth. On these several constituent parts of the *pyrites*, I shall take notice of what I take to be subservient to my principal view.

To begin with *iron*, as the principal constituent part of the *pyrites*. In general, it deserves to be remarked of that metal, that it consists of a metallic earth, proximately arising, above all others, from the crude, undetermined earth itself; as, among other things, appears from the following observations. (1.) In moisture, particularly in the moist earth, it very easily turns to a rust, consequently to an earth; which can be said of no other metal, but lead and copper, which change, the

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one to cerus, the other to verdigrease, tho' neither so quickly, nor in such quantities. Nay, such an earth, especially that from iron-ore, shall, according to Becher's peculiar experience, so very much degenerate, and turn to a mud and loam, as to lose all metalleity *. (2.) Iron also, by fire, turns sooner to a rust and earth, than copper, lead, tin, and quicksilver, which subsist longer: and this rusty iron-earth, particularly that procured by means of the air or water, and which, in various views, is now called sinter, now ochre, now yellow, so nearly resembles, in tenderness and fattiness, an universal, yellow-brown, marl-earth, as to be undistinguishable from it. (3.) Amongst ores, iron in the pyrites, next to cinnabar and antimony, holds the most sulphur, but parts with it much easier than they, even spontaneously; and though in the mercurification and regulation of cinnabar and antimony, it must separate the sulphur, yet it takes a little to itself. Copper retains sulphur more obstinately, fluxing and caking together, rather than parting asunder. The lead in lead-glitter, or galena, will neither so easily separate from its sulphur, but rather vitrify into a cake; though here, as for antimony, iron is used with advantage, for parting the silver: regulus and quicksilver go forth with the sulphur, rather than part with one another. In a word, iron has too coarse, and sulphur too subtile an earth, to be able, though strongly operating on each other, to mix and combine together lastingly. (4.) Iron, by cementation, takes a much less quantity of sulphur than copper does; for, equal parts of sulphur being conveyed on glowing iron, and glowing copper, the former comes to have about an eighth, the latter a full third part combined to it. (5.) Iron, as well as some other metals, refuses to amalgamate with

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* Phys. Subterr. p 595.

quicksilver; a circumstance to be ascribed to its earthiness, as to a crude, unprepared metalleity. In the next degree to iron stands copper, which also resists quicksilver, as we shall afterwards perceive. (6.) Iron is a metal generable not only from all sorts of crude, particularly loamy, claikey, marly, fatty earths, as Becher's famous experiment shews, but also gives itself forth, both by nature and art, from vegetable and animal earths, and thus from earths already derived from the mineral kingdom; as *there*, M. Lemery shews *, by the magnet, from wood reduced to ashes; M. Seipius †, from a piece of wood found reduced to iron in a certain spring: and I myself, in my small collection, can shew from the like peculiar pieces from Bohemia; and M. Liebknecht §, from the like samples: and here, from the bones of men turned to iron ||. Now I would gladly see half these observations, nay, Becher's single experiment only, as easily applicable to other metals. So greatly does iron differ from all its sister metals, as to claim the right of primogeniture! Only we must guard against running into the alchemistical conceit of the other metals being derived from iron. And here we may, with Stahl **, justly complain of Becher's not having distinctly enough communicated Paracelsus's experiment on the transmutation of iron into lead.

Now, since a crude, loamy, and slimy earth may so easily become metallic, particularly iron, 'tis no wonder we should look for an iron ore in claikey, luty, shivery, talcky, loamy, &c. beds: and

* Hist. de l'acad. &c. Can. 1706.

† Vom Pyrmonter Sauer brunen. p. 51.

§ De ligni in mineram ferri facta metamorphosi.

|| Acta Erudit. An. 1682.

** Spec. Bech. p. 159.

and since the *pyrites* is there so often to be met with; besides, no other mineral so very common and plentiful in all sorts of stone and earth; and iron, so universally present in all *pyrites*, nay, in many other ores, 'tis more still to be wondered that the ancients should have overlooked it so much, and turned their thoughts on copper only, to the quite disregarding the iron-yield of the *pyrites*; in which respect Agricola himself seems also to be at a loss. And, so far as I can learn, Dr. Martin Lister *, was the first, or among the first, who seems to be aware of iron being the capital constituent part of the *pyrites*, or the first who clearly expressed himself in this matter: *Pyrites purus putus ferri metallum est*, the *pyrites* consists entirely of iron; though (when in another place he says, *unus Angliae pyrites, purum putum metallum est*, one sort of *pyrites* consists entirely of iron) I much doubt, whether he was quite so sure of the truth of his former enunciation, and whether he knew to give it its full latitude, and true extent. Among the Germans, together with the celebrated Dr. Hoffman at Hall, the famous Dr. Berger claims the honour of the discovery, as he has solidly shewn in his excellent treatise on the Carlstad baths †. As to myself, I had some difficulty, at first, to admit of the vast extent and spread assigned the iron in all sorts of *pyrites*; nor were my doubts removed by consulting either smelters, or the writers on natural history, but by a careful examination of the several sorts of *pyritæ* themselves, and that with no small pains and expence; by that means only I came to be fully convinced of the truth of what Lister and Berger had writ to that purpose. What made me call in question the assertion of these great men was,

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* De Fontibus Medicatis Angliae, p. 43. Ib. p. 19.

† Bergeri Commentatio de thermis Carolinis.

that those *pyrites*, which, with us at Friberg, give only a few pounds of copper, are no longer called *pyrites* absolutely, but *copper pyrites*; and that those containing ten, twenty, thirty, and more pounds of that metal the quintal, cease to be called *pyrites*, and take the appellation of *copper-ores*; that, however, many, nay, most *pyrites*, with us at Friberg, are not purely martial, having some small matter of copper in them: but, in fact, I soon discovered the above assertion to have all the justness and solidity that any other proposition in mineralogy could possibly claim: and my experience in *pyrites* has been so extensive, that, without hesitation or reserve, I may aver, all the sorts of them, the *white*, the *yellowish* and *yellow*, in regard of metal-yield, to consist either entirely of, or to hold *iron* in equal quantity; or should the *iron* be exceeded by the copper, yet still to maintain its rank as a constituent part thereof.

Therefore I assert more than what, I think, the above authors have done, namely, that *iron* constitutes the ground-earth of all sorts of *pyrites*; a truth to be met with in no other author that I am acquainted with, though no great art be requisite for making the discovery, being what is easily found by only the magnet; a circumstance that seems to do no great honour to our care and attention, as thus the most common and obvious things often escape our knowledge; not to mention the subtilities and empty speculations of philosophers, who, overlooking the information of the senses, rather confound than clear up matters.

The Hessian *pyrites* from Almerode, called *terra martis Hassia*, and *Solaris*, but from what hea-

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ven I know not; the round *pyrites* of Alt-sattel, not far from Egra in Bohemia; the *pyrites* from the Schloßberg of Toplitz; also that round *pyrites*, easily crumbling or falling to pieces in the air; and the *periwinkle* and *muscle pyrites*, are, all of them, a pure *iron-pyrites*, without any the least copper; also excel all others in the fineness and purity of their sulphur. In a word, the *pyrites* of Acidulæ, Thermæ, and other medicinal springs, nay, all *pyritæ* in general, that ever came to my hands, and were ever found at mines, in fissures and veins; or that only break in clay, loam, sand, shiver, lime, and other stone-quarries, are, with respect to the metal, almost all pure iron, only that they are often intermixed with a little copper. In Misnia there is neither mine, nor vein, of what kind soever, coarse or noble, at what depth soever, in what direction or point soever of the compass; no ore or stone, of what nature or name soever, where the *pyrites* does not mostly and principally consist of *iron*, the copper adhering to it being scarce visible, much less educible. All the copper-ores of the following Misnian mines, viz. the Halsebrucke, Kuhſchaft, Hohenbircke, Kro-*ner*, Braunsdorff, Kayser-Henrich, Zwolf Schlus-ſeln, &c. are never without copper and *iron*; nay, often contain more of the latter than of the former.

One proof of this proposition, namely, that *iron* is the ground-earth of all sorts of *pyrites* the magnet supplies us with, and so much the more infallible, is this proof, as we know of no other body thus acted on by the magnet; though its force may be spoiled, or impeded, upon over-burning, especially in an open fire, and reducing the *pyrites* to a brown-red, rusty earth: but this earth may again

again be made to answer the magnet, if, by a due smelting, its metallic fattiness be again procured to it. All *pyrites*, without exception, desulphurated in close vessels, answer the magnet equally with smelted iron, and a genuine *iron-stone*. Even the *pyrites*, that contains copper in no great quantity, is acted on by the magnet ; that holding much as ten, twenty, thirty, and more pounds the quintal, not so strongly, but more or less in proportion to the copper it holds ; but the copper predominating in a greater proportion, the virtue of the magnet proves more weak and effete, or has no effect at all. The magnet also exerts some efficacy on the *misspickel* of Friberg, and the *poison-pyrites* of the Obergeburge.

In order to know what sort, and how much of other metals the magnet can bear, so as to continue to exert its virtue ; I, by it, after desulphuration, examined different *pyrites-copper-ores*, and plainly found it attracted them all, though not within the same sphere, nor with the same briskness of activity, as it does the pure *iron*, or poor copper *pyrites* ; but by it I could not discover the exact proportion of *iron* and copper in each, and, consequently, how much copper the magnet can bear in the *iron*, without losing its virtue thereon ; only I observed a greater efficacy exerted on one sort, as the *pyrites* of Ilmenau and Sweden, than on those from Lorentz-vein, near the Halsebrucke ; those from the Kuhshaft, Kroner, Kayser Henrich, Goslar, &c. in general ; but then 'tis not possible, in an intelligible manner, to specify the particular degree of attraction. Again, I am not sure, whether the *pyritæ*, which here, in respect of the magnetic virtue, are to be compared together, have always gone through one and the same degree

degree of fire. For, according as a copper-ore happens to be burnt too little, or too much, the magnet manifests a greater or less degree of briskness on it: and should I attempt the making a proof or two only, it would be impossible so exactly, in the other proofs, to hit again on the due length of time, and the proper degree of fire: or, should I work several proofs at once, as, for that end I have constructed my reverberating furnace for desulphuration, one and the same degree of fire could not possibly be applied to each apart: not to mention, that of many ores I have only employed small parcels, being only provided with such; whence 'tis easy to judge, a small parcel may be sooner fitted for the magnet than a larger: and lastly, 'tis probable, *pyrites-copper-ores* do, together with the two capital metallic earths, contain also a crude, unmetallic earth, and that in various proportion, and which is neither to be weighed nor measured. So that, besides the copper, there is something else in the *pyrites*, that hinders and weakens the effects of the magnet.

But, still more certainly to discover the proportion of copper the magnet can bear in the *iron*, I melted both these metals together in different proportions; as for instance, filed *iron*, and filed copper, in various layers, committed to a crucible, with a flux consisting of two parts of the black flux, and glass, and one of borax and salt of tartar, to between one and $\frac{1}{2}$ and two parts of metal, and found the magnet could bear in the *iron* half the copper; nay, I doubt not, a greater proportion, which I cannot at present ascertain, as several proofs miscarried with me. Being engaged in these experiments, I was willing to know what, and how much of other metals the magnet could suffer in *iron*, and the result was as follows.

(1.) *Iron*

(1.) *Iron* dosed with the above salt and glass, even in the briskest fire of a wind-furnace, not to be brought to flux without calcination and reduction. (2.) *Iron* making a black slag. (3.) *Iron* refusing melting with lead, and always swimming a-top, unless previously divested of its metallicity, and reduced to an earth; whereas, otherwise, in its metallic form, intimately entering into all metals and semi-metals. (4.) *Iron* burning away sooner than copper, because more difficultly smelting. (5.) *Iron*, to be acted on by the magnet, bearing as much gold as copper. (6.) Also as much silver. (7.) *Iron* entering tin, forming therewith a regulus, on which the magnet strongly acts. (8.) With zinc forming a malleable regulus, like silver, yet hard, and not backward to the magnet. (9.) *Iron* going into bismuth in such sort, that tho' the brittle regulus thence arising, be considerably impregnated with, nay, consist of above $\frac{3}{4}$ bismuth, yet, notwithstanding, answering the magnet. (10.) *Iron* melted along with brass, continuing still subject to the magnetic virtue, where the calamy is still observable from the yellow cast of such iron. (11.) The magnet also bearing regulus of arsenic, prepared by means of iron. (12.) Bearing fly-stone, sublimed from misspickel, or poison-pyrites; also the being smelted with iron. (13.) But not at all bearing the regulus of antimony in the iron, though I have made the trial in various ways; neither the *lapis de tribus*, though metallizing with iron; a circumstance I as much admire, as others may be apt to disbelieve it. I shall further add, from my experience, that from iron and tin, a quintal of each, I have procured one quintal and $\frac{1}{2}$ of regulus; from four quintals of bismuth, and one of iron, four quintals and $\frac{1}{4}$ of regulus; from —— quint-

— quintals of *iron* and antimony, four quintals of martial regulus of antimony.

A second proof for the universality of *iron* in *pyrites*, we have from antimony, seeing on the *pyrites* the sulphur of the antimony is equally consumed, as on forged *iron*; depositing, especially with the addition of proper salts, the regulus, so far forth as the pulverized state, to which the *pyrites-iron* must, by the desulphuration, be reduced, will permit: so that the very few *pyritæ*, wherein the copper entirely predominates, cannot reasonably be supposed to affect our proof, as the existence of such an *iron* metal-earth seldom can be denied.

A third proof we have from the vitriolisation of *pyrites*; all *pyrites* giving forth a vitriol, as they all hold a sulphur, excepting the *misspickel*, when pure and unmixed with other *pyrites*. All sorts of vitriol, whether native or factitious, are either purely martial, purely coppery, or consisting of both: the first is of a sea-green cast, and sweetish taste; the second blue, and tasting sharp and nauseous; the third, wherein the martial predominates, may conceal its coppery nauseous admixture from the sight, though not from the taste. In short, all vitriols consist (1.) of the strongest mineral acid, which comes either from sulphur, or the air: (2.) of a metallic earth, which is always either *iron* or *copper*, or both together, though in different proportions; whence all the vitriols, as they are called, from silver, lead, &c. made by means of aqua fortis, vinegar, &c. cannot be classed with the abovementioned. As to pure coppery vitriol, it will be a hard matter to find any such; for though the *cement waters*, as they are called, or, properly, the *copper-waters* of Hungary,

gary, and other parts, do, by throwing in *iron*, let fall the finest sort of copper, it does not follow that they are purely coppery, seeing there are few pure *copper-pyrites* in nature: and such *pyrites* as naturally turn to vitriol, cannot do so without some admixture of iron; but a pure copper-vitriol must be solely prepared from fine, smelted copper; or otherwise, by art, and with the greatest attention separated from mixt vitriol. The third sort is the most common and universal at mines and huts; and, whether native or factitious, it will, upon proper trial, particularly upon a due separation, be found to be mixed. The first sort is, nevertheless, not so very rare, that we need go in quest of it as far as Almerode in Hesse. But tho' our sulphur and vitriol *pyrites*, as they are called, generally contain some copper, yet, by a due evaporation, and crystallisation, of such vitriolic admixture, a considerable quantity of pure *iron* vitriol may be procured.

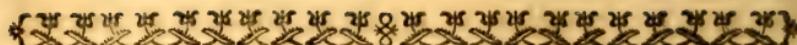
(4.) It is also observable, that the regulus procured in smelting for copper-ores, and called *black copper*, has that black colour chiefly, if not always, from the *iron* such ores happen to contain: moreover, there is no one sort of copper-ore, that remains untouched by the magnet.

(5.) I might here also alledge those scoriæ, which, in copper-ore proofs for silver, always arise dark and black; whereas, doubtless, had there been no *iron*, the colour would prove of a liver, a brown-red, even to a high-red cast, the proper colour of copper: for though lead, without which no *incotion*, or *scorification*, can possibly be made, should happen to mix with it, yet it could not entirely destroy the original colour of the copper;

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as little as it does the black cast of the scoriæ of iron-pyrates, though it bring them somewhat nearer to a brown. I shall leave to further reflection the vitrification I performed, without *additions*, in a glass furnace; where, both from copper-ore, the common pyrites, pure sulphur-pyrates, and the arsenical, as the *mispickel*, and mock-lead, I usually procured a black, dark glass.





C H A P. VII.

Of the COPPER in the PYRITES.

NEXT to the iron, the principal metallic earth to be looked for, and met with in the pyrites, is *copper*. *Pyrites* is never without iron, often without *copper*, which, next to iron, *pyrites* most affects, and which, of all other metals, is the nearest allied to iron; as may appear from the following remarks. (1.) I own there is no experiment extant to ascertain the transmutation of iron into *copper*, though a great deal has been said to that purpose; the error having, at least, arisen from the vitriolic waters of Hungary, wherein a precipitation, rather than a transmutation of *copper* happens by means of iron. As Lohneiss * mentions the like to happen at the Rammelsberg; and the late M. Heineman, inspector at Bottendorf, made an ingenious imitation to that purpose; and I myself, but lately, to my great satisfaction, in the tin stock-work at Altenberg. As to the arsenical *pyrites* of Sweden, from Gothe-gruffwan in Westmanland, which, after some years exposure in the air, is said to turn entirely to a *copper*, this proves to be either a mistake, or a bare hear-say, without any foundation †; yet, I imagine that a transmutation among imperfect metals, supposing such a thing possible, should soonest of all happen between iron and *copper*. (2.) *Copper*, next to iron,

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* Berg-buch, p. 332. Toll. Epist. Itin. V. p. 192. Wedel. in Ephim N. C. Dec. I. Ann. VI. VII. 1673, 1676.

† Leopoldi Epist. de Itin. Suecico. p. 82.

is the most universal metal in nature, there being scarce a vein, whether of lead, tin, or even of the richer sorts, without it; though there are veins of pure copper-ore, without any admixture. (3.) Along with the sulphur in the *pyrites*, copper exhibits much such a mixture as iron does, only that in one the colour is somewhat more yellowish, in the other more pale: and in this resemblance other ores do not equal the *pyrites*, though they may one another: for instance; sulphur with lead, sulphur with regulus, also, by means of art, sulphur with tin, have a considerable resemblance among themselves. (4.) *Copper*, 'tis true, does not emit its sulphur so readily from its ore as iron does, but rather runs, and cakes together; and therefore will not bear any violence of fire, but only should be treated with a soft degree of roasting: and when, by the interposition of quartzy, mock-leady, and the like stubborn sorts of earth, their running together, or caking, is prevented, the sulphur also the more readily separates. (5.) Both of them, in one and the same manner, receive again the sulphur by cementation; only that the *copper* is somewhat more penetrated by it, also retains more of it, and for a longer time. For the rest, both of them, along with sulphur, form a rusty, footy mass; whereas the white metals, and the semi-metals, usually, by its means, acquire a glittery, antimonial, and thus a more *ory* form. (6.) All imperfect metals, without any one addition, may be made to burn away, or rather lose their metalleity, and turn to an earth; yet none so easily as *iron* and *copper*. Stahl * supposes this to happen sooner to the latter than to the former, but, in my opinion, equally to both; though, from my proofs, which are difficult to be made

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* Specim. Bech. p. 298.

accurately, I cannot support the contrary; only so far I observe, that both metals, if not suddenly committed to a very brisk degree of fire, throw off scales, which hinder the smelting; nor do they recover their metalleity even by the strongest pitch of fire, without *additions*, but turn to a scoria or glass: which remark, in regard to a sudden brisk fire, may be also made, with respect to the other metals, particularly lead and tin. (7.) Iron and *copper* are the only two metals, which change to a proper vitriol, a thing not to be affirmed of any other. Whence (8.) it appears, that these metals are of an equal fitness and texture to receive the mineral acid, whether from sulphur or the air; tho' indeed with some inequality in this receptibility, which is greater in iron than in *copper*; whence the latter appears to be of a closer texture than the former; particularly such a body, as returns not so readily to its universal *terreity*, but is arrived to a more heightened degree of *metalleity*. Nay, (9.) they both lodge well together in a vitriol; and tho' at last by a careful evaporation, like all other saturated salts, they may be considerably separated from each other, yet the *copper* with difficulty parts from the iron, after having once been in contact with it. (10.) Next to iron, *copper* is of all metals the most difficult to flux in the fire. (11.) *Copper* is also the hardest metal: whence, among the ancients, in defect of iron, it was used for making swords and scythes; as in the cabinet at Stockholm a sword of that metal is still to be seen, and the like usually to be met with in ancient graves*. (12.) In both, preferably to the other metals, gold finds a lodgment and an aptitude for generation; yet more so in *copper* than in iron. (13.)

Copper,

* Elvii & Benzellii *Schediasma de re metallica Sueco-Gothorum*, p. 14.

Copper, next to iron, amalgamates with mercury with the greatest difficulty; whereas gold and silver amalgamate with ease; also lead, tin, and zinc most readily. (14.) The magnet chiefly and in greatest quantity bears copper in iron.

Whence, *a priori*, 'tis easy to see, what probability there is for copper to lodge along with iron in *pyrites*: and, *a posteriori*, or from examining the *pyrites* itself, what just foundation there is for that probability. But, as copper is not common to all the sorts of the *pyrites*, some containing pure iron only; and consequently, as the *pyrites* may subsist without copper, so copper must not be considered in the same light as iron: namely, as an essential part of the *pyrites*. But in regard the incidental existence of copper therein extends so very widely, that (1.) very few *pyrites* are without it; (2.) many copper-pyrites have a large copper-yield; nay, some of them, almost to a half; so, next to iron, this metal deserves our greatest attention. Though I would not dispute the excluding such copper ores, as come very high in yield, from the class of *pyrites* in general, and the putting them in a peculiar class by themselves; and then considering the copper therein, not as something incidental, but as a necessary part of that ore. Only we must not, with the Ancients, run to the other extrem; namely, that of neither regarding, nor looking for any other thing in the *pyrites* but copper, as if they never contained any iron.

Hence it has happened, that vitriols have no one name assigned them, denoting their iron; being indiscriminately called *chalcanthum*, *chalcitis*, *cuperosa*, or *cuprirofa*, &c. And this has so far prevailed, that not
y 11 Greece and Italy, but even in Germany it-
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self, all sorts of vitriol, even that principally from iron, have to this day no other appellation than that of *copper-water*; the iron being considered as something incidental, even by modern mineralists.

Copper, however, has a very extensive spread in the *pyrites*; in regard to place, *yield*, and also *mightiness*, as miners usually speak, with respect to the breadth and thickness of their veins. As to place, there is scarce a mine, without some appearance of *copper-ore*. 'Tis found in all sorts of earth and stone; in shiver, lime-stone, quartz, spad, kneiss, and gemſs: though it generally appears, that the *pyrites* in clays, lutes, and lime-stone, are for the most part principally *irony*; and often pure and unmixed; whereas *copper-ores*, either poor or rich, must be sought for in quartzy, spathy, shivery, and the like stone. *Copper-pyrites*, or ore, *breaks* at different depths; in some places, in *day veins*, as has been said above, almost beneath the under-turf-earth; though rarely, and as may be easily imagined, thinly sown, and not so *mighty* as in the *depths*; in other places, and more frequently, in the *depth*; of which the famous mines at *Fablun* in *Sweden* are pregnant instances.

Here I have often put the question to myself; whether the *pyrites* does, with the depth, decrease in iron, and increase in *copper* yield; namely, with this view; whether the common *pyrites*, employed in making sulphur and vitriol, and in the operation of *crude-smelting*, and in metal pure iron almost decreases with the depth; that is, becomes weaker or smaller in veins? or whether, like other ore veins, as *lead* and *copper*, it rather increases? And to mention only the *pyrites-copper-ore*, it is well known, that downwards it still grows *mightier* or *larger*;

larger; whereas the *pyrites* iron-ore, that runs from above inwards, loses itself more and more, upon the encrease of the former. Whence it may be probably conjectured, that iron and *copper* are, in regard of their proximate metallic ground-earth, if not one and the same, yet greatly resembling each other, and differing only in the degrees and periods of coction, maturation, and exaltation: particularly, that those particles, which, in the *iron-pyrites*, were to be carried no higher than to the form of iron, are, in the *copper-pyrites*, on the contrary, or *copper-ore*, to be raised to a higher and nobler form; that is, to that of *copper*, as what requires a different and a more thorough degree of coction and maturation.

What confirms the conjecture of the iron and *copper pyrites* having the same original (in particular, that the *one* is derived from the *other*) is, that the *copper-pyritæ* seldom begin from the *day*, or beneath the under-turf earth; whereas the *iron-pyritæ* commonly manifest themselves there; nay, where the former happen to appear soon (which nevertheless is rarely observed) the latter do not only equally as soon manifest themselves in huge beds, *stock-works*, *bellies*, and *nests*, but are also gradually accompanied by the former. Yet all this does not fully satisfy the query; the nature of the *deepest*, that is, of the sole or bottom of the mine, as far as it has been sunk, being besides to be considered.

Now, here again we are not to doubt, but that *iron-pyritæ* lodge also at the greatest depth, even in the center of the earth; it being possible, that the same causes, that operate near the surface, should also exist at the greatest depths. Our experience and knowledge are, however, not sufficiently

ciently extensive, fully to answer this question, a great deal of attention and caution being requisite in forming a proper judgment on the case.

Now, as to the *copper-yield* in each sort of *pyrites*, whether denominated *copper-pyrites*, or *copper-ores*, I have in various ways attempted to discover it, without leaving concealed the smallest share of *copper*, that happened to be therein. As to those that contain much *copper*, or only a *pound* the *quintal*, the method of extracting it is a thing well known: if first, according to the common way of assaying, they be brought, in their unroasted state, by means of pounded glass, to *crude-stone*; which *crude-stone*, with the usual dose of *black-flux* in a crucible in a wind-furnace may be reduced to *black-copper*; and this again in the assay-furnace to *rose-copper*; tho' to procure the *copper*, on the score of its being apt to burn away, from extremely poor *copper pyrites*, care and experience are requisite. And, as I have had several sorts of *pyrites* from our mines, from which neither I, nor the most experienced assayer, could extract the least *copper*, I have discovered other ways to answer the purpose. The colour I found to be fallacious; and even extremely pale *copper-ores* to be rich in *copper*, this paleness arising from the defect of sulphur, and the over-dose of arsenic.

These poor *copper-pyrites* I tried both in their crude and roasted state, nay even in their iron-regulus, with vinegar, also spirit of sal-ammoniac; as these are sharp waters, which *copper* readily yields to; but without the *copper* giving forth its green and blue colours, on account of their being entirely defended by the iron: and when any green cast happened to manifest itself, it was owing to a coppery iron.

iron-regulus, and to *pyrites*, where the *copper* shewed itself bodily by the common proof, without the trouble of torturing with vinegar, &c. Lastly, I proceeded with them in the way of a vitriolisation, both by means of the air and fire, opposing such vitriol to a pure martial sort, made by art from iron by means of oil of vitriol; and thus sufficiently pure from all *copper*: yet there was no difference of colour observable; though upon tasting it, its nauseousness failed not to manifest itself. But a vitriol, mixed with some alum, though otherwise entirely free from iron, as is often the case of that from shivery and black kneiss, *pyrites-vein-stone*, as is that of *Braunsdorff*, and the Hungarian native vitriol itself, causes such a degree of nauseousness on the tongue, as though it were coppery, that it is no easy matter to distinguish them: as I was long unacquainted with this, I could affirm nothing with certainty about it, but was again obliged to have recourse to iron, which at length extracted the *copper* out of such vitriols and *pyrites*, wherein I never suspected any such thing to be. The method in short is, to dissolve the vitriol in common water, and put a polished iron wire therein; when the *copper*, though in the least quantity possible, not only visibly colours the iron of a *copper-red*, but also crusts it over with a kind of *copper skin*, whilst the iron in the mean time consumes away, and partly goes into the vitriol mixture, and partly falls down to the bottom; and this so long as there remains the least *copper* therein: so that this is the best way of purifying a coppery iron-vitriol, as shall hereafter appear more at large.

After premising in general the *yield* of other ores, we shall in particular treat of that of *copper*. As to the noble metals, gold and silver, their *yield*

in some ores, namely, in the *glassy* and *red-goldish* sort, is considerable, or at least so far constant, as that the former, when pure, and without any rocky admixture, affords always above a half, and commonly about two thirds: the latter also, when pure and fine, usually above a half in silver, and never less. But then we must here regard the proper and essential characters of such ores; as no ore is to be accounted a *glassy* sort, that will not bear the being cut, hammered, &c. A *red-goldish* sort may also happen to have some foreign admixture, as appears from its dark cast at *Braunsdorff*: and thus in proportion to such admixture, its yield falls short of half. But in most ores, the yield in noble metals is so variable, that there is no coming at near so much certainty for these, as for the *glassy* and *red-goldish* ores.

Lead-glitter, or galena, holds sometimes a half, sometimes a whole *lotb*, sometimes two, three, ten, and more *lotbs* of silver; not to mention a sort, that rises to *Marks** the quintal; among which there break noble veins, in particular of *white goldish* ore, tho' often very unobservable. *Copper-ore* also, in regard of its silver-yield, greatly rises and falls: and here I have observed, that when it comes to *lotbs*, it is of a dark-grey cast, and then called *fallow copper-ore*; and when to *marks*, this dark-grey hue remitting somewhat, it comes to be called *fallow ore*: nay, the *white-goldish* ore, which, so far as I could learn, is certainly a *copper-holding* sort, only so far differs from *fallow ore*, that sometimes in silver-yield it has risen very high, namely, to ten, twenty, thirty, and more *marks* the quintal, and on the contrary, falls in *copper*: and thus the *white-goldish* ore cannot, like the *red-goldish* sort, properly con-

* A mark in the language of assayers is half a pound.

constitute a class of silver-ores; as being not only highly inconstant in silver-yield, but peculiarly *cupery*, which can never be said of any red-goldish ore.

As to the imperfect, or rather, ignoble metals, their ores are in more instances found of a constant yield than those of the noble; as in particular, we learn from *lead-glitter*, *white* and *green-lead* ore, *tin-stone*, *iron-pyrites*, and *cinnabar*; *glitter*, or *galena*, commonly containing two thirds, nay somewhat above, in lead; and hitherto I have found none falling much short of a half. The same we observe, and that with more certainty, of no one ore so much as of the rich *tin-stone*. *White* and *green lead-ore* hold ordinarily above three fourths in lead, and never under, only allowing for its incredible volatility.

Sulphur-iron-pyrites always yields about three fourths metallic, namely, *iron-earth*; and allowing for its volatility, neither more nor less than a fourth of sulphur. *Arsenical*, or *poison-pyrites*, which has also constantly an *iron-earth* for its ground, when pure and fine, has a like yield, allowing only for a third, or somewhat over, of *fly-stone*, or *arsenic*. *Cinnabar-ore* has often somewhat foreign in its *mixtion*; thus not always exhibiting its due, beautiful, red character, but sometimes appearing of a brown-red, more or less, almost like a *brown-red iron-stone*; but when arrived to its true degree of perfection and purity is, like the other, found in its proportion of sulphur and quicksilver, as 1 to 6 or 7. And here it were to be wished, assayers were more careful in noting down the several *yields* of their ores, not omitting at the same time to register any doubts that might arise in the course of the process: as by this means

we

we might by degrees arrive to certain axioms, that might be depended on, with respect to the metallic *mixtion* of ores.

Some of the above-mentioned ores, namely, antimony and *lead-glitter*, agree more than a little, both in their measure of sulphur and metal-*mixtion*; also in the kind of their volatile, namely, sulphur portion; nay, almost in the volatility of their metallic or semi-metallic portion; and besides, in the separability of their metal from their sulphur. In particular, that these, before all or most other ores, are in their *mixtion* found of a like proportion of metal and sulphur, as that their metal, at least, ever outweighs the remaining ore-portion, but the contrary never happens. Farther, that accordingly, *tin-stone*, cinnabar, *glaſſy*, and *red-goldish* ores may be classed amongst the first, of whose metallic *yield* the most solid and constant observations may be made.

Now to return to our *pyrites-copper-ore*; I have not only assayed various sorts thereof, but employed all the care and attention needful on such occasions; as separating, picking, and cleaning; and found their *yield* seldom amounting to half, nay, generally falling short by 3, 2, down to 1 pound; consequently a yield so various, as is not easily to be met with in any other genuine ore; a circumstance that deserves a greater degree of attention than has hitherto been thought proper to bestow upon it; not to repeat what was said of lead, quicksilver, and regulus of antimony, whose proper, pure ores in metallic *yield* never fall so low, nay constantly hold to one and the same degree of weight, without any material difference, allowing for what is lost, from their aptness to volatilise, to be

be burnt away, and to scorify, nay, from inattention and negligence in the operator. The same may with more propriety be said of tin, whose proper, pure ore, called *tin-stone*, also *tin-granates*, constantly give the same, and that a rich yield, namely, above a half. This great variety in the *copper-yield* of *pyrites* affording us no certain axioms or truths, puts us upon the necessity of framing so many classes of them, as there are different *yields*; and therefore copper is to be considered as something incidental to *pyrites*.

It were to be wished we had some external signs or characters, whereby to ascertain the different *yields* of the *copper-pyrates*. The density, closeness, and weight of the ores are not always to be depended on. Their structure, which is either *stellate*, *testaceous*, or *run*, or *melted together*, as it were, so far manifests the difference of their internal substance, as to shew that the *stellate pyrites* commonly contains no copper at all, or but very little; those consisting of different coats, to be generally arsenical; in which respect they are here at Friberg called *cobaldish*, nay *cobald* itself; but as to those masses of *pyrites*, which appear melted, or run together, it still remains a difficulty to determine their yield. The colour proves a surer guide in this case; the more yellow and greenish the *pyrites* shews, the richer it proves in *copper*: yet, from the absence of these colours, the absence of *copper* must not be inferred. For though this inference might in most instances hold good, especially in regard to some one particular *mine-work*; for instance, that of Friberg; yet the above-mentioned sample of a certain *copper-ore* considerably white, such as I never once after saw, heard, or read of, might caution us against entirely and solely

solely relying on the colour. The surest way therefore of judging of these ores, where the structure affords no light, is, together with their colour, to take their weight, density, and glittering, shining appearance into the account. True it is, the above-mentioned *copper-ore*, which yields to the quantity of 40 pounds in the centner, appears very pale, and almost like a white *pyrites*; but, on the other hand, from its density and closeness, it must be of a more metallic nature, and not barely a white *pyrites* or *misspickel*, but a body only invested with arsenic, and thence ought to be imagined to be more *coppery*. But what judgment then are we to form of the *fallow-ore*, *fallow copper-ore*, *copper-glass*, and *copper-lasul*? *Fallow-ore* is a grey sort, darker than the *white-goldish*; containing between 1 and 2 marks of silver, usually *breaking*, as we see at the *Croner* and the *Halsebruck*, with yellow *copper-ore*. *Fallow-copper-ore* is darker than *fallow-ore*, and therefore expressly denominated from *copper*, as containing more of that metal, and much less silver.

Copper-glass is still darker, inclining much to a black, as being highly irony. *Copper-lasul* distinguishes itself by its steel-blue colour, though misuse has introduced the calling a yellow-greenish *copper-ore*, a *copper-lasul*. Among the ancients *copper-glass* denoted only a *copper-lasul*. But here to obviate much difficulty, these ores, but just mentioned, may well be excluded the class of *pyrites*, as not properly belonging thereto; though I thought it necessary to mention them, as they serve to clear up the business of ore-colours; and, in particular, to find out the marks of *copper-yields*. That the iron in the pure *iron-pyrites* appears not black, or as an iron-stone, but yellowish, is solely owing

owing to the sulphur; without which there is nothing to be found in the pure *iron-pyrites*, capable of imparting such colour to the iron. That such *iron-pyrites*, whose sulphur is only mixed with some arsenic, deviates from a yellow more to a white, is undoubtedly owing to the arsenic. That nothing but the *copper* heightens the yellow colour of the common iron and sulphur *pyrites*, and makes it run to a greenish, is a truth as little to be doubted of. But why a *pyrites-copper-ore*, containing 20 pounds of *copper* in the centner, is not so eminently distinguishable in colour from that which holds only 10; and why it is often a difficult matter to know a very rich from a considerably poor sort, three reasons seem assignable: one certainly is, the arsenic, which imparts its high colour to the *copper*, as is well known from the operation of *white-copper-making*, and prevents its coming to that degree of yellowness or greenishness, which *copper*, with sulphur, is wont to exhibit: and thus sulphur is more copious, nay, as it were, more indispensably necessary in *pyrites-copper-ore* than in *pyrites-iron-ore*; as the *sandarachy*, or ruddy crude sulphur, always procurable from the *copper-pyrites-ores*, sufficiently shews.

The second reason is the proportion of the sulphur in respect to the remaining principles of the *pyrites*, being what I found pretty uniform and constant in the pure *iron-pyrites-ore*; but in the *copper-pyrites ore* not only in general, in a smaller, but also a more variable quantity.

The third reason probably may be derived from a circumstance, of which I shall make some mention in the following chapter; namely, an unmetallic, crude, undetermined earth; which,

as in many other ores, so also is it to be met with in the pyrites; and which, both in respect of quality and quantity, may serve occasionally to heighten, or to lower the colours of ores.

This third, together with either a defect of sulphur, or a plenty of arsenic, may be a concurring cause, why the often mentioned rich *copper-ore* of Hohenstein, has acquired so very pale an appearance, that were it not for its uncommon density and closeness, it might easily be taken for a yellowish *pyrites*, or for what it really is not. In such circumstances, we must be upon our guard in judging of the *pyrites* by their colours, at least we must not suffer ourselves to be misled by the pale; though in such things, where many circumstances must often be considered together, colours afford the greatest light, as was observed above, chap. II.

Lastly, I must add, that in the white *pyrites* there is no copper at all. Now, whether any, or how much *copper*, there may be in *kupffer nickel*, a sort of cobald, of a *copper-red*, and allied to the white *pyrites*, is a thing that must be previously enquired into.

C H A P. VIII.

Of the UNMETALLIC EARTH in the PYRITES.

THAT along with the iron and copper in the *pyrites*, there is, besides, a fixed sort of *earth*, which is neither sulphur nor arsenic, neither iron nor copper; in a word, which neither is itself, nor can yield, any metal, is a thing deserving a particular consideration, as being one of the peculiar principles of the *pyrites*. Upon this head we shall briefly only (intending to leave the further disquisition of the subject to the more minute examination of others) consider these four things; (1.) What we are to understand by such an *unmetallic earth*: (2.) Whether such an *earth* is to be observed in other ores: (3.) Whether such can be shewn actually existing in *pyrites*: (4.) What its nature and properties are.

As to the first, or what is to be understood by the *unmetallic earth*; we must, first of all, guard the reader against a mistake, in which he might be otherwise apt to fall, and caution him, that by no means are we to understand by it the adhering, interspersed, quartzy, spathy matters, and the like *earth*, rock, or stone, or any thing that is separable by the wedge, or distinguishable by the naked, or even by the armed, eye; seeing sometimes in ores there lies interspersed, like a sand, a small-grained, either quartzy or selenitical, sort of rock, or stone, as I have had a sample from the Bannat of Temeswaer, in which an unarmed eye could

could scarce distinguish it. I must here also obviate a false notion, which, notwithstanding the above hints, some might be induced to form to themselves of what we call *pyrites-kidneys*, and balls; wherein, upon breaking them in pieces, we often observe all manner of sandy, stoney, and often scarce distinguishable particles, falsely considered as essential parts in the mixtion of the *pyrites*. I have lately had one such kidney, above a pound in weight, from the salt-pit at Bochnia in Poland, where neither externally, nor for an inch deep within it, was to be found the least trace of a rocky, or other admixed matter, as an essential, constituent part of the *pyrites*; but, quite internally, I unexpectedly observed such; of which the *pyrit* periwinkle and muscle samples are plain, palpable instances. But, by the *unmetallic*, fixed *pyrites-earth*, we are rather to understand such *pyrites-particles*, as are intimately introduced into the *pyrites-mixtion*; namely, an earth, both by the volatile and fixed earth of the *pyrites*, so swallowed up, mineralised, and incorporated, as to be as little distinguishable as the other *pyrites-particles*, the sulphur, arsenic, iron, or copper, either by the naked, or armed eye.

This unmetallic earth, like the other principles of the *pyrites*, is derived, as was shewn above, from the generation and production of the *pyrites*; from ore and stone-forming juices, conveyed in the manner of damps, or vapours for that purpose.

(2.) As to the question, Whether such an *unmetallic-earth* may be found in other ores, I must own, it was the *pyrites* gave me the first hint of this sort; as in it I found something which could neither

neither be called sulphur, nor arsenic, nor a metallic earth: and, to confirm this, I examined other ores, and found a like earth in cobald and bismuth ores. Cobald, which is used for making smalt, tolerably resembles the *arsenic-pyrites*, or the white *pyrites*, or *mifnickel*, both externally and internally; only that this last turns to a very dark glass, whereas the first has its earth changed to a beautiful blue glaſs. Now as the white, or arsenic *pyrites*, has ſome iron for its *ground-earth*, which undoubtedly is the cause of the black colour of its glaſs; and as the tint and colour of glaſſes commonly bewray ſomething metallic, as appears, not only by *analysis*, but by *synthesis*, as in the making of ſimalts, or enamels; ſo all blue mineral colours, whether natural or artificial, as laſul-stone, copper-blue, mountain-blue, blue vitriol, arise only from copper. And laſtly, as copper shews itſelf plainly in that ſort of cobald, called *kupfernickel*, it is not improbable, ſimalt may be produced from an earth, not only, in general, metallic, but, in particular, coppery: but as from cobald, by any method hitherto understood, only a very ſmall quantity of metal, either of copper, or any other mineral, is procurable, that bears any proportion to its earth, we muſt needs ſuppoſe its ground-earth, if not all, yet moſt of it, to be *unmetallic*, crude, vague, or undetermined; particularly, *crude-earthly*, sandy, and thus eaſily vitrifiable: but the cobald to be employed, muſt be no *mixt-work*, but ſuch as is highly pure, and carefully ſeparated from its quartz, which not only externally adheres thereto, but often lies very tenderly and inseparably interspersed or mixed amongſt it; otherwife it would yield an over-quantity of *unmetallic earth*. This genuine ſimalt-earth is generally as one to three, in regard to the volatile, arsenical, portion; the arsenic be-

ing what has penetrated, impregnated, and formed the said earth, so as not to become a bare stone, but an ore, and such a sort, as greatly resembles a metallic, in particular, a grey, coppery, and silvery ore. Bismuth-ore, which is greatly allied, and adheres also to cobald, leaves behind, after roasting, (in which operation it yields a semi-metal, called *bismuth*, or *marcasite*) an earth, or stone, called *bismuth stone*; this earth, like that from cobald, affords a more beautiful smalt, but no metal, in what manner soever treated.

(3.) With respect to the manner of exhibiting this *unmetallic earth* in the *pyrites*, we shall take notice of each of the three principal sorts of them, beginning with the white, or arsenic *pyrites*; after separating the volatile portion of which, there remains behind, in close vessels, a reguline, semi-metallic body, called *fly stone*; but in an open fire there sublimes a grey, whitish meal, used for making arsenic, leaving behind it an earthy, or stoney substance, that looks greyish, is very light, and generally amounts to about $\frac{1}{3}$. Now, that in this *earth* there is metal, nay, iron in particular, cannot be denied, forasmuch as it is greatly attracted by the magnet, and, in part, by means of proper additions, may be brought to yield an iron-regulus, nay, an iron-vitriol. But (1.) the iron is in a variable proportion therein, whereas the proportion of the entire fixed earth, with respect to the volatile part, comes pretty near to an equality. I have remarked, that not only one sort of *arsenic-pyrites* earth is more affected by magnetism than another; nevertheless, that it preferably turns to iron, as I have had an instance of a sort from Fahlun in Sweden. (2.) But this *white-pyrites* iron is in a very small quantity, that is, scarce $\frac{1}{10}$, in com-

comparison of the remaining fixed earth. (3.) This unmartial residue is by no methods reducible to any other metal ; and tho' in the intended metallisation many actual iron particles may be scorified, or vitrified, as may easily happen in iron, nay, in copper proofs, with an undue degree of fire, or dose of *additions*, yet this cannot always be the case ; and certainly we have reason to believe, that the glass, or scoria, to which the fixed white *pyrites earth* runs, is mostly a crude, *unmetallic earth*. As to the yellowish, or sulphur *pyrites*, there is, by the magnet, and the usual *smelting-proof*, more iron in it than in the white *pyrites* : so that some of them amount to 50 or 60 lb. of iron in the centner, or quintal ; whilst others, or rather the most, in particular the spherical, and those the purest *iron-pyrites*, seldom yield more than between 10 and 12 pounds. And again we see, that, besides the sulphur part, which is generally about $\frac{1}{4}$, and the metal, which is not $\frac{1}{2}$ of the $\frac{3}{4}$ parts of the fixed earth, including also the scorified iron-earth, the half or above the half, which is neither sulphur, nor metal, must be a crude earth. Lastly, of the copper, or yellow *pyrites*, we may affirm the same as of the yellowish, as being nearly allied to each other.

(4.) What the proper nature of this *unmetallic earth* may be, cannot so easily be determined ; we must therefore rest contented with the bare knowledge, that there is, in reality, such an earth, tho' incapable of exhibiting it pure and in its unvitrified state. I call it a crude earth, because from it, as from an unformed matter, a metal may be produced, if either the matrix prove not barren or untoward, or there be no want of impregnating juices, or of a proper length of time for completing the maturation and coction.



C H A P. IX.

Of the SULPHUR in the PYRITES.

AFTER having treated of the metallic, as well the martial as venereal, and of the unmetallic earth, and consequently of those parts of the *pyrites* which are fixed, we now proceed to consider the others; and first, the *sulphur*, which is a body peculiar to the mineral kingdom alone, as no one sort of ore is to be found without it; some partake of it in a larger, others in a smaller proportion; though it is scarce, if at all, to be found mixed with tin, bismuth, and cobald: it mixes indifferently well with arsenic, also gold, more readily with silver, and still more so with lead, iron, and copper, but, above all, with quick-silver, and regulus. As to tin, I never yet met with any tin-ore, that shewed the least trace of *sulphur*, but rather a pure *poison-meal*, or arsenic; though this tin ore be not easily separable from *wolfram*, a kind of mock-tin, or an irony tin mineral, which must therefore have some *sulphur*. A genuine smalt-cobald, in this respect, greatly resembles tin; and from bismuth-ore, as such, to extract any *sulphur*, would be more than a little extraordinary. Arsenic, when contained in the mineral called *poison-pyrites*, or *mispickel*, may admit of some *sulphur*, but smalt-cobald with none; a circumstance worth remarking.

Further, though regulus of antimony be so nearly allied to bismuth, as appears by a variety of experiments,

periments, and tho' the former is entirely impregnated with *sulphur*, yet that the latter should not bewray the least appearance thereof, is something uncommon.

Silver manifests still more of it, not only that incidentally lodged in other sulphurated ores, for instance, lead glitter, copper-ore, and *sulphur-pyrites*, *white-goldish*, *fallow* ores, and *fallow-copper*-ores; but in its own peculiar ores, as the *glassy*, and, in some degree, the *red-goldish* ores.

As to gold, it is not certainly known with us, how far, and how readily *sulphur* lodges in it, as I have not hitherto seen a proper gold-ore; and as it is still a question, whether the spangles of gold, to be met with in veins, are not rather native, that is, only lodged there, and not in an ore-state, or mineralised by means of *sulphur*; yet I would not maintain the impossibility of such a state, nay, rather hold, that, where 'tis reduced to genuine ore, it is so, not by means of arsenic only, though principally, but also of *sulphur*; besides which, there is no third body in the whole compass of the mineral kingdom, so capable of reducing metals to an ore-state.

But be this as it will, *sulphur* is more readily found along with lead, copper, and iron, as appears from lead-ores, copper *pyrites* and ore, and iron-*pyrites*, yet not so peculiar to these metals, as it is to regulus and quicksilver; seeing iron-ore is sometimes to be found without any distinguishable *sulphur*, such as most iron-stone is, in particular, *glass bead*. Copper-ore I have found without *sulphur*, as, a copper-lasul from Lapland; also lead-ore, entirely without any, as appears from the

white and green lead ores ; but to find quicksilver-ore and regulus without *sulphur*, would be a prodigy in nature.

Sulphur is more frequently found with the ignoble, rather than with the nobler metals, in their ore-state, and with it, sometimes, arsenic is combined in larger or smaller quantities ; a circumstance not to be affirmed either of quicksilver, or regulus.

Iron and copper, as well as quicksilver and regulus, greatly affect *sulphur*, which, when without all other metals, is never without both these last ; and in the former too in so large a quantity as in the often mentioned metallic middle substances, or *electra*. In a word, *sulphur* reduces iron and copper to an ore-state, and forms them into *pyrites* ; yet not always in the same manner, or proportion.

As to the white *pyrites*, I, for a long time, doubted whether it contained any *sulphur*, 'till a person, employed in the manufactures of *sulphur* and sandarach, would, right or wrong, persuade me, that a sandarach might be made from white *pyrites*, without *additions* ; whence it follows, that it must necessarily contain *sulphur*, without which no sandarach can be prepared. But to omit mentioning now, that I never could discover any by my repeated proofs, I found it to be a bare assertion, without any foundation ; a thing but too common, both at the mines and huts. I cannot, however, deny to the white *pyrites* (though entirely close as steel, pure, and without any observably interspersed *sulphur-pyrites*) any the least matter of *sulphur*.

In *copper pyrites*, as that holding but little copper, is thus called at Friburg ; and *copper-pyrites-ore*, (by which

which I mean what is there called copper-ore, or the *pyrites* rich in copper) posses *sulphur* in such plenty and proportion, as might almost make it looked upon, not as an incidental, but as an essential, constituent part thereof; and this so constantly, that let a *copper-pyrites-ore* be ever so arsenical, it is never without *sulphur*. And here the following remark may properly be made, namely, that *iron-pyrites*, so far as the *white-pyrites*, on account of its very small portion of iron, may be called such, may sooner exist without *sulphur* than *copper-pyrites*.

In genuine *iron-pyrites*, containing the least, or no copper at all, the *sulphur*, in general, amounts to between $\frac{1}{4}$ and $\frac{1}{2}$ of the whole. To mention only the principal sorts; that from Ehrne-Schlange gives 28 pounds of crude *sulphur* the centner, or quintal; from Pretschendorff, 30 lb. 24 loths; from the Rautencrantz, at Johan-Georgen-Stadt, 30 lb. 24 l. from the Halsebrucke, 36 lb. 16 l. from Braunsdorff, 25 lb. 16 l. from the Schloßberg, at Toplitz, 27 lb. 16 l. from Almerode of Hesse, 26 lb. 12 l. from Alt-sattel, near Egra in Bohemia, 26 lb. 16 l. from Boll, in the territory of Wirtemberg, 26 lb. the *shiver kidneys* of Goslar, 24 lb. the Swedish *pyrites* of Nericia, 25 lb. the *pyrite-kidneys* from the salt-pit at Vilizka, 26 lb. the *pyrites* from the Banat of Temeswaer, 27 lb. 10 l. the *pyrites* from the three Wisemen's Levels at Schemnitz in Hungary, 23 lb.

And here we are to remark, (1.) That in close vessels, as retorts, the above assigned proportions of crude *sulphur* are with difficulty, and commonly scarce to one fourth procurable; but an open fire, such as is that under the muffle, fully forces out what

remains behind, which is doubtless a *sulphur*, as appears from the odour of the exhausted *pyrites-earth*, though not to be retained.

(2) The *pyrites*, that in crude *sulphur-yield* exceeds one third, is to be suspected to partake of arsenic; as is the case of the *Haljebrucke pyrites*, which, in its *sulphureous*, and other volatile portion, amounting to 36 pounds in the center, and consequently above one third is remarkably arsenical, and therefore called *cobald*.

In *pyrites*, impregnated with arsenic, as is commonly the sort where copper lodges along with the ground-earth, it proves a difficult matter to make a calculus of the *sulphur*; such *pyrites* readily caking, and running together in the fire, and the more so, by how much richer it is in copper; the reason, doubtless, is principally owing to the arsenic; for, the *white pyrites*, which abounds in arsenic, does the same; that is, running together, it usually cakes: so that the arsenic to the *sulphur*, in the *copper-pyrites*, or copper-ore, rarely exceeds one fifth or one sixth.

Now, the *sulphur* procured from *pyrites*, particularly from the yellowish, or the sort called *iron* and *sulphur pyrites*, generally manifests a yellowish grey cast, and is occasionally called either *crude sulphur*, because it comes from the first process, and is still unpurified; or *caballine*, or *horse sulphur*, as it is proper enough to be used for diseased cattle. This *crude*, or *horse sulphur* is re-committed to the retort, and once more distilled or fined; whereby it turns out beautifully yellow, pure, and fine, the foreign arsenical matter, called *sulphur-flag*, remaining behind at the bottom of the retort.

I can-

I cannot omit suggesting here something very remarkable; whether to call it a new discovery in mineralogy, particularly in the doctrine of *sulphur*, I know not; which, in short, is this, that in the *crude sulphur*, there is an actual iron-earth contained, which not only is readily acted upon by the magnet, but is also *metallised*.

For if you take the *sulphur-slags*, and burn them in a crucible or pot, you procure a greyish, ashy earth, which the magnet attracts, and which, by proper additions, may be reduced to an iron-regulus; and this not only when the *sulphur* is treated in an iron retort, the using which might give suspicion of the acid salt of the *sulphur* having corroded and dissolved some of the iron of the pot, but also in earthen retorts.

We have here besides two remarks more to make: (1.) That the above is a certain truth, which may often clear up an experiment, that may happen to be made with *sulphur-slags*, and contribute to attain the knowledge of a natural body; whether the iron it holds, happen to be derived to it in an incidental manner from the vessels, in the course of the purification, or in the first *desulphuration* sublime along therewith from the ground-iron-earth of the *pyrites*.

(2.) The more clearly to disclose my thoughts on this head, I am in general to enquire, whether it would be any absurdity to suppose the tender iron-earth, as it is in the *pyrites*, to be at the same time volatilised in the *desulphuration* of the *pyrites*? The copper-earth is, however, fitted for this volatilisation, as the copper-particles in the *pyrites* adhere

here more closely to the *sulphur* than the iron-particles do. But all that can be hence inferred is, that the copper-particles may be more adapted for volatilisation than the iron-particles are ; as it must be allowed, that the grossest earthy metal-particles, as iron and copper, nay all imperfect metals, may barely, by the action of the fire, without any additional assistance, be volatilised.

What may help to remove all difficulties, is the having in our eye the two following important and repeatedly confirmed rules :

(1.) That some matters, when accompanied, or combined with something, even not so essential to the design, usually shew themselves, both *passively* and *actively*, of a very different habitude ; either more adapted and active, or more powerful and operative, than when employed separately.

(2.) That metallic earths are in their mineral state of a quite different aptitude, than when brought into a metallic body, and smelted. Silver, as a metallic body, will be readily allowed to remain unvolatilised, but combined with common salt, will prove fugitive. The vitriolic acid is one of the most powerful, penetrative, active things in nature, yet deprived of the inflammable earth it possesses in the *sulphur-mixtion*, it can never produce the same effects that it does, when treated in the form of *sulphur* : and the effects of sulphur itself upon metallic earths are owing to its combined state in the mineral of *sulphur*, namely, the *pyrites*.

The grounds of these two practical rules depend sometimes barely on giving a steadiness and body to

to the matters under treatment, that they may not go off too soon in the fire, but have time either to work or to be worked upon; as we see from the production of *sulphur*, where the alkali is only given as a body to the vitriolic acid; sometimes on intimately mixing different things together, though in themselves improper for the intended proceſs; when new combinations, qualities, and effects, must needs be produced.

Now, to apply all this to the volatilisation of the iron-earth of the *pyrites*; it is certain, that this is not so easily effected with iron itself, as with the iron-particles, still existing in the ore or *pyrites*: and what is decisive, take a *crude sulphur* made in clay vessels, distil or burn it off, and examining the earth remaining behind, with the magnet, *this latter* will be found to attract the *former*.

Whether, and how far, the coppery earth goes in part over, in the distillation, or *desulphuration* of the *pyrites*, along with the *sulphur*, as I have not been able to make *John Agricola's* experiment, must be left to be considered, and rest upon the truth of his relation, which is as follows:

' Having once made an *oleum sulphuris*, or oil of *sulphur*, the *fæces*, or remainder, I reverberated for fourteen days in a moderate fire; afterwards committed them well luted down to a wind-furnace, giving for six hours a strong fire; then I wanted to calcine the *fæces* quite white, as my intention was to make something else of them. Now, upon breaking up the crucible, I found on the upper part, a few *fæces*, not white but grey, and beneath, a beautiful regulus, of a blood-red colour, and very sparkling. I wondered

dered what it might be, as being well aware, that not the least thing, besides the sulphureous *fæces* had come into the crucible. Upon taking out, it proved heavy, and tried under the hammer, it stretched almost like lead : upon clipping with the sheers, it proved internally somewhat yellowish, but a beautiful fine copper, which gave me no small surprize. The goldsmith also, upon wire-drawing it, found it not only malleable, but of a very beautiful colour. Upon a repeated ignition and extinction in urine, it had almost acquired the colour of *crown-gold*. It has been often matter of reflection with me, why I procured no other metal but copper ; for, I well knew this *sulphur* was not derived from a copper, but from a gold pyrites. But at last I found the reason : for, though there was not any one mineral or metal added, only the *sulphur* first dissolved in linseed oil, from which no metal can arise ; I thus concluded, that a strong metallic spirit, tho' deemed only an excrement, and forced off by a strong fire, lodges in the sulphur *.

Many things in this relation want to be cleared up, and much to be remarked upon. In the first place, it is pity our author did not specify the quantity of the *sulphur* employed, and of the copper educed ; a piece of inaccuracy but too common with writers on these subjects. Again, he is under a mistake, in that he considers linseed oil, as of little use in the business of metallisation ; since it is not a bare transient but an immanent instrument, or rather materially contributes thereto.

His making *gold pyrites* and *copper-pyrites* two different things is a mistake, as I have sufficiently shewn

* Joh. Agric. über Poppii Chymische Aitzneyen im tractat. de sulphure, p 855.

shewn above, chap. III. There are so many *pyrites* containing copper, that scarce one in a hundred is without it, or that consist entirely of iron. A *pyrites*, that, preferably to another, yields gold, must always possess iron or copper, or both, for its ground-earth. And I have remarked, that such *pyrites* are ever coppery, nay the very richest copper ores ; and, in the other case, ever purely arsenical, or the *white pyrites*. Now, in the last place, whether it was an actual *gold-pyrites*, or no, we are to understand, that *pyrites* breaking in fissures and veins, is seldom without some little copper. So that our author might have saved himself many uneasy reflections about the causes, whence his copper might arise ; and also have spared himself the trouble of imagining a *metallic sulphur spirit* ; as he needed only to have put the alternative ; either the copper is along with the *sulphur* educed bodily out of the *pyrites* in form of the most subtil earth ; or generated, as a new production, out of the *sulphur*, or its peculiar earth, with the addition of linseed oil, or its fatty earth ; also for a certainty, with the addition of the material, fatty particles of the fire.

It is, however, probable, the above copper was not generated but educed : for, in the first place, the volatility, or at least, the volatilisation of all imperfect metals in general, is a plain case. (2.) We have a peculiar instance in iron, which is most proximately allied to copper. (3.) The *sulphur*, which must here serve as the vehicle, adheres longer and closer to the copper than to the iron. (4.) The volatility of copper assayers experience but too often, upon too briskly roasting its ore ; when they remarkably educe a less quantity of copper, than when together with care and time they employ a gentler fire.

Now

Now according as the *pyrites*, out of which this and the other *sulphurs* are driven, the *sulphur-flags* of each sort procured, happens to be very irony or coppery, so the earth remaining behind of these flags, may at one time take more iron, at another more copper. Yet it may well happen that in the course of *desulphuration* and purification, some change of iron into copper particles may be effected, by means of the energy of the *sulphur*, as both those metals are proximately allied to one another : by this change or transmutation, no wide leap, but an easy transition rather is produced in nature ; not only to the *patient*, namely, the metal, standing highly receivable, but the *agent*, namely, the *sulphur*, in the rank of one of the most powerful in nature ; that if common *sulphur* doth not transmute iron into copper, or rather does not fit an irony earth for a coppery one, it will remain for ever untransmuted.

As to the habitude of *sulphur* to the metal-earth, entangled therewith in the *pyrites* ; it becomes a necessary question, whether either the *sulphur* arose at the same time with, or whether it gave rise first to the metal-earth, and thus existed previously to it.

That all *pyritæ* were not originally created, but generated at different times since the deluge, and still continue to be generated, is a certain truth, as I have shewn in chap. V. Now let any one imagine to himself a luty, loamy, and the like marly earth-bed, which is peculiarly adapted for the conception of such ore ; I there find only one sort of particles, either not manifestly such, or in all respects the same as the *pyrites* consists of ; and, as one

one might be apt to imagine, such as it might be supposed to be run together and formed of.

We shall omit mentioning the metallic ground-earth, as being what is at least *in potentia*, so that nature may, with ease, completely fit it for the *pyrites-mixtion*; nay, which already appears to be pretty well fitted; as art, which is far from being able to call in aid such auxiliary means, or far from having that time for the purpose, shews the possibility, from *Becker's* famous experiment on loam and linseed oil, of such earth being proximately fitted for the production of iron, also of *pyrites*. But we would only enquire, from whence the *sulphur* is to be derived to it? On the spot, where the generation is to happen, there is none.

But it will, for instance, be alledged, that such a lute, wherein the *pyrites* appears to run nest-wise, must, e'er the production of the *pyrites*, have been of quite a different mixtion and nature from what it is at present; so that its present state renders it unfit for any further conception. Now, should we ever allow the places for the production of minerals, partly in the state the creation left them, partly as the deluge has affected them by new mixtions to become more unfit by exsiccations, exactions, indurations, nay, even petrifications, whence shall we then derive the *sulphur* to the *pyritified* periwinkle and muscle-shells, which doubtless owe their rise to the deluge? Should it be even present upon the spot, and such earths happen then to be of a quite different mixtion and nature, from what they are at present, yet it is impossible to conceive, it was formally and actually present, or that flux-wise, like a *sulphur* melted in the fire, being brought thither, it had, like a seed, collected and lodged

lodged itself in certain cavities and matrices, and there concocted, penetrated, and elaborated the matters it met with, and lastly, hardened them into such lumps, balls, *kidneys*, and *nuts*, as we find.

To come to the truth of the matter as near as may be; if not to a positive demonstration, yet a high probability, let us consider those bodies called *druse* and *sinter*.

Upon both these we, among other ores, find *pyrites*, not in a flux or run state, but as so many small stones or crystals, in figure like the following salts; *viz.* *tartarus vitriolatus*, *arcandum duplicatum*, common salt, &c. which thus usually shoot from their several waters. These cubical and variously angular *pyrites*-*corpuscles* fit so loose upon the rock and tacks of the *druse*, as to make it evident, they did not sprout out of the subjacent rock itself, but were sprinkled or sown thereon: and really the case is so; namely, that they are damp wise sprinkled upon these bodies, as I have shewn above, chapter V.

The question therefore is, whether those parts of the *pyrites*, we afterwards discover upon resolving it, existed in the mineral damps in a determined, formal, actual state; or, whether they were not first formed and produced in the course of forming the ore itself? A question of some importance, as it no ways follows, that because upon analysis, we find the *pyrites* principally to consist of sulphur and iron; that therefore it is also necessarily produced from the same materials; nor that, as many might be apt erroneously to imagine, the *sulphur* is the metallizing principle; things that lodge near, and in each other, are not always to be taken for the natural

mutual origin of each other; though *sulphur*, when actually present, and chiefly in its ore, must be allowed to have some efficacy. The mineral damps, that lodge any where for mineralisation, may happen to be of different *mixtions* and natures, yet, doubtless, in their particles, are still in an undetermined, and, as it were, *chaotical* state; in which, though caught and examined fresh, neither the *sulphur-earth* apart, nor the metal-earth; neither the *dry*, nor the *moist*, are separately distinguishable: either they are found in a kind of seminal state, wherein the parts of the body to be formed are not yet distinctly exhibited or elaborated, tho' they lodge *potentially* therein. And though the receptivity and re-action of the bed or matrix, length of time, the accession of different matters, and other accidental circumstances, have undoubtedly much influence on the formation of different ores; yet I affirm, that in the production of the *pyrites*, we ought to imagine an *influx* of actual *pyrity*, formally *sulphureous*, and corporally *metallic* damps; but to the formation of *sulphur*, *pyrites*, and *metal*, damps proximately and reciprocally adapted, are necessary.

For, in the first place, from the opposite opinion, it must be presumed possible, from *sulphur* and iron earths, to make, or compound the *pyrites*; but of this there neither is, nor ever can be any instance: and farther, supposing that art could exhibit any such experiment; where shall the metal-earth, in the laboratory of nature, be found to be added thereto? On the *druse*, as being quite pure and close, it is not to be met with; and yet there the *pyrites* is often found in great plenty and large masses; to suppose it sprinkled along with the

L.

sulphur,

sulphur, by way of damp, in a metal form, is as difficult to reconcile with experience.

Pyritæ resolve themselves into their present constituent parts, and forsake their proper mixtion, as shall be shewn in the chap. on vitriol; but these parts thus forsaken, do not therefore remove from each other, nay, do not separate from each other, even for a single moment; but in the course of that motion which brings about the dissolution of the *pyrites*, the sulphur-acid swallows up the iron-earth, and becomes conjoined again in a different manner: what remains separated from this new vitriol-production, may well be deemed no other but the metal-earth; and as to the *sulphur*, there is little or nothing saved, but generally all of it is destroyed; yet as there is certainly much *sulphur* acid requisite to the production of vitriol; nay, from the very small metal-yield of the *sulphur*, and so much metal-earth or ochre residue, we must conclude, that were there more *sulphur* in the *pyrites*, more vitriol would have been generated, and thus more *sulphur* become incorporated with the iron in the vitriol.

Thirdly, there are other ores that may happen to be somewhat *sulphureous*, and dissoluble, and by their dissolution yield *sulphur*, and form *sulphureous* damps, or *weatherings*, and yet be less adapted to the production of matters, or damps fitted for *pyritification*; wherein the parts of the *pyrites*, especially the metallic, shall (if we allow it to contain the *sulphureous* parts) formally exist; seeing all other *sulphur*-ores, that are not *pyrites*, afford no iron, as the latter do.

Fourthly,

Fourthly, from the structure or texture of the *pyrites*, particularly the round sort, we see it is become what it is, through length of time, and by means of coction. The round sort is either testaceous or radiated, and by both ways of structure, it exhibits such proofs of its origination, as are not to be sought for from an external accumulation, but from an internal concocting, fermenting, transmuting elaboration: I say, from the origination, or formation of *pyrites*; (and this I mean not of the configuration or external form, but of the internal essence and mixtion of the *pyrites*;) for, indeed, an accumulation, not of matters actually *pyrit*y, but of matters adapted to such productions, must both be granted, and must happen. Yet in clayey, loamy, shivery, marly beds, where *pyrites* is peculiarly found in *kidneys*, so large an accumulation of matters, derived from other quarters, is not so much to be expected, nor is it necessary (as there the subjacent fine earth, at least the iron portion, contributing to the formation of the *pyrites*, is already proximately prepared for it; which, to its concentration, collection, and mineralisation, together with some acid, or even sulphureous damps, only wants some degree of coction) as in those *pyriteæ* rather, that lay upon *druse*; where nothing earthy is observable; from which, as from a *substratum*, so much metallic matter, as is to be found in *pyrites*, could have been generated.

Upon the whole, the *sulphur* in the *pyrites* first truly becomes what it is, and was not before formally therein; in the same manner as other fixed *pyrites*-earths, which, (previous to the *pyritification*, were crude, though not so very foreign to

this work) must by coction be more proximately prepared, and rendered metallic.

Now, in order to answer the question; viz. what analogy the *sulphur* in the *pyrites* has to the metal-earth, we must here distinguish the times. First, if by it we intend only the primordial origination of the *pyrites*: in this sense, the sulphur in the *pyrites* is not the *metallising*, nay, not the *mineralising* principle; for, how should it, when it did not exist? And though the inflammability of mineral or mineralising damps shews somewhat of a *sulphureous* nature, yet it does not follow, that they are positively *sulphureous*: thus the acid of such earth-weatherings shews a part, and not the whole of the *sulphur*.

But, were we to speak with propriety, not of the *sulphur* itself, but of the parts that are to become *sulphur*, it ought to be observed, that in the business of generation, the matter may be considered as *active* and *passive*; the former as the most tender, fugitive, and penetrative; and the latter (or what is to become the metal) the heaviest, coarsest, and densest: though in generations, that is, in productions of a third thing out of two others, both parts so act and re-act, as thereby to form a new production.

(2.) If by the question be meant the analogy of the *sulphur* to the metal-earth in the *pyrites* already formed, such as we find it: to me it seems like the juice, in respect to the remaining dry body; or, as a material cause and property of *mineralety*; according to which the *pyrites*, like all other proper metal-ore, is distinguished from a formal metal,

or

or formally metallic earth ; on which score, *pyrites* may be called, neither an iron-earth, nor iron itself, but a *sulphurated* iron, or iron-earth : and lastly, that the *sulphur* and iron-earth are mutually moved or acted upon by each other, and connected together, like two members or links in a chain ; where there is neither *agent* nor *patient*, but both are equally *passive* ; in which case a third body must intervene ; as happens in the vitriolisation of the *pyrites* ; where not only the chain, but each link therein, breaks asunder, namely, the *sulphur* in particular, ceases to be a *sulphur*, and commences to be, what it must be, for exhibiting a vitriol.

This third consideration leads me to a circumstance the most important of all, and which gave occasion to this question, which otherwise may possibly appear useless ; namely, an opinion, that the metals in the ores do, by means of the *sulphur*'s activity, not only grow, but become more ennobled : a surmise, which, if it doth not unhappily betray the enquirers into all the false conclusions and vain idle processes about metals and their melioration, yet it helps to prevent the discovery of other useful, practical truths. For, tho' we are ready to confess *sulphur* a very powerful principle in the mineral kingdom, yet in any capital imitation of nature, we are not to strain or over-do our conceptions of it.

Where then is the *sulphur* or agent in such processes, when two bodies, which partly are only a crude, unsaline, unsulphurous, nay even unmercureial earth ; and partly, a metal already smelted out of its ore, come together into union, and such a degree of motion, as that the first not only incorporates with, but also proves similar to the second ;

consequently, to be corporally metallic, nay a noble metal; as the celebrated *Stahl* knew an instance of a certain earth and a silver; and which was not unknown to other operators? And is then fossil calamy, which not only tinges, but also in its very substance enters into the body of copper, and therewith becomes metallic, a *sulphur* also, or derived from *sulphur*? I cannot find it is.

Finally, *sulphur* certainly is a powerful, active, mineralising, and peculiarly operative matter, not only in respect to that metal-earth, with which it was blended, and constituting, for instance, the *pyrites*-mass, but also, after separation from the *pyrites*, or any other body, in regard to other foreign earths, with which, after due preparation, it is put in a proper degree of coction: and this is the third analogy of *sulphur* intended by the above question.

The first was the analogy of the *sulphur*, or rather of the parts that were to become *sulphur*, to the metallic earth, or the earth that was to become such, as we may conceive it in the first formation and production of the *pyrites*. The second, the analogy of the *sulphur* in the *pyrites* already formed, as it now is, in a seeming state of rest or inactivity. The third, its analogy, out of its mineral, when separated from it, or even left therein, and something else applied, with which, by means of the external warmth, it may be brought into action.

'Tis however certain, *sulphur* manifests something that is active, powerful, and operative, nay maturing, graduating, and transmuting, both in its separate and combined ore state; sometimes

times more one way, sometimes more another, according as the subject happens to be qualified by nature, or prepared by art; also according to the nature of the fire, the process, and other circumstances.

As to *sulphur* in its separate state, 'tis certain, it mineralises, or reduces metals to an ore-state: in particular, this holds good of lead, which it reduces to a form, tho' more earthy and footy, and thus very indistinct; yet such a one, as will here and there easily manifest small eyes of *glitter* interspersed.

It reduces also to an ore-state the regulus of antimony, so as to make it greatly resemble a crude antimony. It turns quicksilver to cinnabar; silver, especially when reduced to that white calx, from which the *Lunæ cornua* is made, to a mass, little or nothing distinguishable from that richest silver-ore, called *glassy*. It also mineralises tin, yet so, as to appear like an antimony rather than a tin ore.

Further, *sulphur* metallises crude earth, from which otherwise no metal would be procurable; yet, with this remarkable difference, that it sooner reduces it to a noble than ignoble metal: as to the production of these last, a part only of the *sulphur*, namely, its fattiness, is better adapted than the whole body of the *sulphur*. It exalts the earths of imperfect metals, and makes them approach considerably near to silver, and probably to gold, as I found by experience, after having found out, and duly worked the proper sort. This I can with confidence affirm of the *reguli* of lead and antimony. And I conclude from experience, that the histories

of the many lead and tin processes mentioned by Kelner, ought not to be rejected, as they certainly carry appearances of what has really happened, notwithstanding many others have miscarried in their attempts, to imitate his experiments. To them also belong the cinnabar-processes, where again the *sulphur* comes principally in play, and which, by passing through the hands of impostors, have fallen into discredit.

On the head of the lead and tin processes I shall only mention, that the business depends, in some measure, on the due preparation of the metal or earth, particularly on its most intimate subtilisation; to the same purpose is also necessary such a degree of warmth, as that the *sulphur* shall just come to exert its activity, without being made to run. As to the *sulphur*, while yet in its ore-state, I have made numerous proofs with *sulphur-pyrites*, and found, that in certain circumstances, there may, in regard to the exaltation of the metallic earths, or the metallisation of the crude earths, something be performed therewith, which is not performable with *sulphur* alone. And this is a sufficient hint, without being more explicit, to a diligent enquirer into nature.

But I cannot help observing: (1.) The extraordinary nature of native calamy; namely, that an earth, such as that properly is, which of itself affords no metal, except a very inconsiderable share of iron, should, upon being mixed with a body appropriated to it, for instance, copper, become almost intirely, as is well known, metallic, and incorporated with the copper, without destroying its malleability, and consequently its true metallic character.

(2.) That

(2.) That taking certain lutes, as chalk, and roasting it softly and gradually along with *pyrites*, a *silver-grain* will certainly be procured, otherwise not procurable from such an earth, and which consequently may be justly affirmed not to be in it, but rather matured, concocted, made, or transmuted by it.

Lastly, That here we seem to discover a foundation, that may tend to the improvement of smelting ores; not to mention the iron, lodged with the *sulphur* in the *pyrites*, which principally contributes to the business of fluxion and separation.

As the metallic earth, joined with the *sulphur* in the *pyrites*, is two-fold, namely, iron and copper, the former at all times, the latter often at the same time therein, it remains to enquire, what their different connection with each other usually is.

(1.) Sulphur endures being separated very easily from the iron earth, so as sometimes to lie loose therein; whereas it clings more closely to the copper earth, insomuch that it is often perceived to flux along with, rather than part from it; as appears not only from copper-proofs very readily caking together, but from the *copper-stone* at the huts; which, after having gone thro' a number of fires, both in roasting and smelting, still exhibits many large lumps in the form of real yellow copper-ore. 'Tis true, arsenic, which always lodges in the copper-ore, but never in pure *iron-pyrites*, may be the means of this closer union; nay, is of itself alone capable of effecting this, and with its metallic earth adhering to it, of coming into an intimate union, namely, into flux; as it directly shews this (upon committing

ting it to a sudden brisk fire in a crucible in the wind-furnace) in *Mispickel*, along with that earth, which, in a great measure, is martial, and moreover, very crude. The reason, doubtless, is, that arsenic, as a semi-metallic body, comes nigher than *sulphur* to a metallic earth. Such union, however, must also arise from the nature of the *sulphur* itself, as shall be hereafter shewn from composition; where I have treated both iron and copper with *sulphur*.

(2.) That sulphur may be found, in a quite crude cast-iron; for we need not prove, but certainly admit, from the history of the operation of *crude-smelting*, and also frequently in forged iron: but then this must be owing to an undue degree of scarification, and consequently to the mineral *sulphur* not being properly separated, as the coarse grain and brittleness of such iron plainly shew: but, if you take a fine tough iron, or, which is better, a steel; must it not then be granted, that, if the *sulphur* educed be not the common mineral, but a proper, metallic *sulphur*, appertaining to the essence of the metal, it should be found in all, even the best sort, as a necessary constituent part: but, from the *ground-mixtion* and essence of iron, there is properly but one, not a two-fold sort, and so far no sulphur to be shewn from any one.

"Tis certain, we plainly observe in *cast* and the like crude iron, sulphur a constant companion, nor is it a stranger in *black-copper*. Now the question is, whether it holds firmer and longer in the iron or the copper.

If we reflect, that the *pyrites mixtion* consists in no such composition as might be supposed to arise from the running together, in concocting and smelting

ing sulphur, and a metal-earth, but in a production or generation, and thus in an internal ground-union, as has been often mentioned ; where then such accurate separations, as that one part shall not either swallow up, force over with it, or keep back something of the other, are neither credible nor possible, the case will prove easy. Again, let us consider what a number of times copper must pass thro' the fire, in roasting and smelting, 'ere it only becomes *black-copper*, whereas iron-stone scarce wants a single roasting, being directly conveyed to the tall furnace.

(3.) Consider only the violence of the degree of the fire in the tall furnace for iron, above that in the furnace for copper ; so that, by the sudden brisk flux, the sulphur separates not so accurately from the metal earth ; but becomes, in some degree, incorporated with the metal ; whereas, by a more gentle fire, it might more accurately and much sooner be separated than from the copper ; as I observed from measuring the time for roasting the proofs of copper ores and iron-stone : tho' there may be instances where the contrary may happen, and this may be owing to this or the other admixture ; yet, it happening more rarely, we must abide by what more generally occurs.

Iron, in whatsoever manner treated, does not so readily as copper admit *sulphur*. The most feasible method I know of is, first, to ignite the metal well, and then convey the *sulphur* upon it ; when the copper actually mineralises, entirely loses its colour and metalleity, turns of a grey cast, almost like a fallow ore, and increases in weight about a fifth : whereas iron not only remains without the least

least increase, but also unaltered in colour and malleability, and therefore not the least penetrated by the *sulphur*. What unsuits iron for receiving the *sulphur*, is its easily burning away, and turning to an earth, sooner than copper, whereby the due introduction of the *sulphur* into it is prevented. 'Tis true, copper, by the art of ignition, becomes covered over with a kind of rust, or scales, which at length, are eat thro' or penetrated by the sulphur; whereas iron will receive none of it, only suffering it to settle a little externally thereon, be the degree of fire as great again as for the copper, and thus be the ingress of the *sulphur* facilitated as much as may be.

Here might be expected a fuller and more particular examination and description of *sulphur*, but as this would require a great deal of time and labour, besides, not properly belonging to our present undertaking, where I enter not into a particular detail of the parts of the *pyrites*, I wave it. My design is the analysis of the *pyrites*, not the history of each constituent part in particular; though, on the score of inferences, connection, and other circumstances, I could not always avoid the hinting at this, and some other matters, not immediately necessary to the knowledge of the *pyrites*.

A reader desirous of something peculiar, fundamental, and explicit on the head of *sulphur*, may consult Stahl, in his *Bedencken vom sulphure*, his *Specimen Beckerianum*, his *Mensis Julius de experimento novo verum sulphur arte producendi*; where he will find full satisfaction.

There still remains to be considered M. Homberg's relation, in the memoirs of the Royal Academy

demy of Sciences at Paris. Now, though Stahl, in his *Bedencken*, has made much mention of it to all useful purposes, yet, as I find this sulphur-history to be still very defective, being proposed by this ingenious person only as an essay, it may not be improper, or unuseful, to insert here, at large, his whole relation (from which Stahl has only selected one single part, or experiment) together with some remarks and experiments of my own; especially as he brings many experiments, which deserve a serious attention in the history of nature. His account is as follows, under the title of, *An essay on common sulphur.*

‘ All those matters called sulphureous, are so entangled and blended with earthy, saline, and aqueous particles, as very rarely to deserve the name of *sulphur*; in chemistry usually applied, without distinction, to the inflammable matters, as, common *sulphur*, bitumen, oils, &c. Sometimes they are also considered as certain materials, especially among minerals, in no manner inflammable, and must be called *sulphur*, merely on account of their colour: so that we see this appellation applied to things of quite opposite natures, and men appear still to have very confused notions thereof, nay, to be almost quite ignorant of what *sulphur* properly is. Now, *sulphur* is one of the most considerable principles in chemistry.’

Here I would hope, that by the term *principle*, he means not a simple or original principle, as will appear from what follows.

‘ Wherefore as in this art it must be known, in order to the forming a rational judgement of it, it appeared

‘ peared to me a matter of importance to examine
 ‘ its nature and characters, and learn to distinguish
 ‘ it from the other principles, &c.’

‘ Common *sulphur* appears to me to have been
 ‘ compounded of several matters; as (1.) an
 ‘ earth, (2.) a salt, (3.) a fatty, inflammable
 ‘ matter, and (4.) some metal. The three first are,
 ‘ in weight or measure in it, in a proportion of
 ‘ equality, nearly, and almost constitute the whole
 ‘ mass of the *sulphur*; from which I premise, that
 ‘ by means of sublimation, it is purified from its
 ‘ superfluous earth, nothing of it remaining, but
 ‘ only so much as the fire could have carried up
 ‘ along with the other principles,’ (rather, that
 nothing of it went over, but what the fire, &c.)
 ‘ the produce of this sublimation we commonly
 ‘ call *flowers of sulphur*. The metal, to be found
 ‘ in common *sulphur*, is in so small a proportion,
 ‘ that it may be overlooked.’

What is become of the water which he afterwards alledges as an essential part of the *sulphur*, though from a false inference? How shall one, from pure refined *sulphur*, which must be what is here meant, make out, and lay down for n° 1. a peculiar earth, that belongs neither to n° 3, nor n° 4, but may be distinguished from both; seeing these two parts are very sparingly, and the last, by his own concession, almost undistinguishable therein?

‘ By a single process, the matters which make
 ‘ or constitute common *sulphur*, are not readily
 ‘ separable from each other, both on the score
 ‘ of their close connection, and on account of the
 ‘ great volatility of the inflammable, fatty matter
 ‘ of

• of the *sulphur*, which almost always carries along
• with it the other three principles.

‘ In a close fire, namely, in sublimation and
distillation, all the four parts of the *sulphur* as-
cend and pass over together, without undergo-
ing the least degree of alteration in their mix-
tion.

‘ In an open fire they are also dissipated toge-
ther, yet, in this operation there happens a se-
paration of the fatty principle, which separates
in the flame, from the saline; the saline unites
with the moisture of the air, and makes what we
call *spirit of sulphur*; by this means setting itself
free from all inflammable fattiness, so that no
remains of it can be observed. This spirit of
sulphur is only the acid salt of this mineral, and,
in every respect, resembles that from vitriol.’

‘ ’Tis difficult to ascertain the quantity of this
acid salt in common *sulphur*; for, the operation
whereby this salt is procured, is commonly per-
formed by the accension of the *sulphur*: now as
no accension can happen without a free access of
air, most of this acid of the *sulphur* is dissipated
and lost; we, however, sometimes procure more,
sometimes less, in proportion both to the skill
of the artist, and the quality of the air. I em-
ploy a peculiar method for the purpose, so as
from a pound of flowers of *sulphur*, to have some-
times an ounce, sometimes an ounce and a half,
as follows.

‘ I take the largest glass receiver I can get, and
make a hole therein, between eight and ten
inches broad; this glass I hang, like a bell, quite
close

close over an earthen pot, which, at the top, is
 about five or six inches in diameter; in this pot
 I previously melt between 10 or 12lb. of *sul-*
phur, 'till quite full thereof; then I set the *sulphur*
 on fire, so as to burn all over its surface; after
 which I place the glass as close to it as may be,
 without extinguishing the flame; the acid spirit
 trickles down into an earthen glazed vessel, in
 which the pot, containing the burning *sulphur*,
 stands upon an inverted dish: in this method,
 which generally succeeds well, between five or
 six ounces of spirit of *sulphur* may be procured
 in the space of twenty four hours *?

A like

* Mr. Seehl, in his paper, containing, An easy method of
 procuring the volatile acid of sulphur, recommends the two fol-
 lowing ways. Process I. Take a pound of the flowers of brim-
 stone, and five pounds of dry fixed alcali salt, grind them toge-
 ther, and put the mixture into an iron pan; add, by degrees, a
 little water, so as just to dissolve the fixed alcali; gradually dis-
 pose the whole to boil, in order the better to dissolve the sul-
 phur; when these have boiled for a quarter of an hour, add more
 water, by degrees, and when the sulphur appears to be dissolved,
 filtrate the solution, evaporate it to perfect dryness in an iron pan,
 'till it almost begins to melt; then take out the dry powder; when
 cool, put it into a tubulated retort, which being placed in a
 sand-heat, and a receiver luted on, pour in at the tube, by de-
 grees, two pounds of rectified oil of vitriol, and immediately se-
 cure the tube with a stopple of chalk, luted, and luting: then
 give a gradual fire for some hours, till the volatile spirit is come
 over; after which, let the fire go out, take off the receiver, and
 carefully pour the liquor into a glass phial, to be closely stopped
 with a glass stopper. The volatile spirit thus procured will be
 about twelve ounces in weight, and appear tolerably limpid, smell
 extremely quick, pungent, and *gassy*, or sulphureous. Process II.
 Take a pound of the flowers of brimstone, four pounds and a
 half of fixed alcali salt, grind and mix them well together, put
 the powder into an iron pan, over the fire, add a little water, by
 degrees, to dissolve the salt, then boil gently for a quarter of an
 hour, add more water, and afterwards three pounds of strong
 quick-lime, let all boil together for a while; when the solution

A like contrivance we find in Lemery's *cours de Chymie*, and which Homberg, but with no small degree of improvement, in regard to the bigness of the glafs, (the former employing only a glass funnel) may have probably borrowed from him.

' This proces, 'tis true, coincides with the usual method by *the bell*, but much altered and improved, as by the former there is much more procured than by the latter method, which is principally owing to two improvements; the first, in the large receiver employed instead of the glass garden bell, which in circumference is much too wide, and in internal capacity much too small and narrow, that but a little can settle thereon, when much must evaporate, and be quite lost; whereas the fitted receiver has a small aperture, and internally a large width, whereby the large evaporation is obviated, and a more abundant collection promoted. The other improvement regards the quantity of the *sulphur*, there being formerly too little *sulphur* put in at once, and that often scarce melted, consequently, the acid not so capable of ascending, especially in such quantity as one would willingly have it; which is so true, that when the pot holds not more than 10 or 12 lb. when not always full, and when the *sulphur* is not thoroughly melted quite

M ' down

is compleat, filtre the lixivium, and evaporate to a dry powder, as in the first process; put this powder into a tubulated retort, and pour on, by degrees, a pound and half of rectified oil of vitriol; proceed to distill, as before; and thus you will obtain about eight ounces of a more strong, and more volatile acid spirit than the former; of a yellowish colour.— Our author owns it was Dr. Stahl's method that gave him the hint of doing the same thing in a better manner.

‘ down to the bottom of the pot, the *sulphur* gradually consumes, and we can procure but little or nothing of the acid salt of the *sulphur*.

‘ You must be careful to clear the upper surface of the burning *sulphur* with an iron wire, or rod, as there settles on the top an earthy skin, which not only of itself gives no flame, but also quite smothers what does ; this only holds good of that *sulphur* which is whitish, blackish, or of a greenish cast, a beautiful yellowish *sulphur* being subject to no such accident’.

Here M. Homberg takes notice of a difference between *sulphurs*, as they happen to be crude and purified, the latter of which must be always of a beautiful citron-yellow, the former being generally of a greenish cast, and sometimes inclining to an orange colour, from its containing something foreign, particularly arsenic, which belongs not at all to the nature of the *sulphur*, and is separable in the refining.

‘ Though this process affords more of the acid spirit of *sulphur* than the common method by the bell, yet still much of it is lost, as may be easily perceived by the strong sulphureous smell about the vessels ; so that hence we cannot learn what is its due quantity and proportion in the *sulphur*.

‘ This acid spirit is entirely separated from its inflammable fattiness, and highly adapted to become a volatile, and almost insipid salt, like the acid spirit of vitriol itself, which it greatly resembles, nay, I might say, is one and the same with.’

What

What our author means by *the volatile and almost insipid salt*, I cannot conceive; a volatile, namely, a spirit of vitriol, becoming *sulphureous* by means of a fatty addition, I well know, and yet so insipid is it, as to be corrosive. I have also a dry volatile acid salt, but powerfully corrosive with all manner of lixivious salts. Would we abstract a spirit of vitriol over lixivious salts, and call what goes over (which is a pure phlegm, set free from its acid salt) an edulcorated spirit of vitriol, as some have fancied to themselves, we might then indeed procure something insipid, but something, at the same time, separated, the acid of which was not edulcorated, but left behind in the alcali; and thus, neither a salt, much less a volatile salt, but a pure plain water.

‘ This then is one of the principles of the *sulphur*, namely, its salt, loosened from its other principles, but mingled a-new with the universal receptacle of acid salts, namely, the moisture of the air: the fatty, inflammable, as well as its other earths, are, by evaporation, lost in the air.’

‘ By the following process I have separated the parts whereof common sulphur consists, so that each may be exhibited apart. Put into a body, or cucurbit of two measures, four ounces of flowers of *sulphur* (or fine-rubbed *sulphur*) pour thereon a pound of oil of fennel, or turpentine, let them stand together for eight days in strong digestion, and the oil will dissolve the *sulphur*, and acquire a highly red colour; let them cool, and you will find the *sulphur*, to the quantity of about three ounces, shot at the bottom into yel-

‘ low needles. Pour off what is still fluid, save it, and pour on again a pound of oil, and set it again to digest, as before; when the vessel is cold, pour off the fluid, and you will find the sulphur remarkably less in quantity: repeat this four or five times, ’till all the sulphur is dissolved. Put all these solutions together into a glafs retort, (because the matter is apt, in the end, to froth much) and distil for twelve or fifteen days and nights, by a very gentle fire, and there will come over about $\frac{2}{3}$ of the oil employed, colourless, and quite clear, and with it about four ounces of a whitish, ponderous, and vitriolic acid water, after this, red drops of oil: then apply another receiver, gradually increase the fire, and in seven or eight hours you will have forced off all you well can: instead of a receiver, you may employ a glass retort: most of the oil turns, at last, very thick and high-coloured, on which still floats something of a whitish, highly acid water: in the retort there remain betwen 2 and $3 \frac{1}{2}$ ounces of a black, spongy, shining, impid matter, which will neither kindle, burn white, nor suffer any remarkable loss in the fire.’

‘ Re-distill the matters found in the several recipients in a very gentle fire, for some days and nights, in order further to separate the remaining oil from the acid water: upon the residuary, bituminous, black matter, pour half a pound of good spirits of wine, and distil very gently; pour again fresh spirits thereon, and repeat this so often, ’till what goes over carries along with it no more bad smell.’

‘ These

‘ These distillations, performed with spirits of wine, carry with them, from the black bituminous matter, those parts of the *sulphureous acid*, that would not come over at the first: now as the spirits may, together with the acid, discharge all the rank smell, which solutions of *sulphur* commonly have, so I am perswaded, the acid of the *sulphur* may be the cause of this intolerable stench:’ (in part, indeed, not solely, but with the addition of a burning fattiness.)

‘ Now, in order to guess at the quantity of the acid and salt procurable from four ounces of flowers of *sulphur*, I took two ounces of salt of tartar, well dried, and dissolved in common water; I poured thereto all the whitish acid water, procured from the said *sulphur*; and, after effervescence, evaporation, and drying, I obtained as much salt as came to above three drachms, sixteen grains.’

Then, according to this process and calculus nitherto, there are in four ounces of *sulphur*, three drachms and sixteen grains, provided M. Homberg has employed enough of the salt of tartar, and something of the *sulphur*-salt unentered into it, did not remain behind, as the alcali, employed for the purpose, appears to me to have been too little.

‘ The first remaining black matter I put into a crucible before the *blast*, and ignited it, when, indeed, it fumed a little, and smelt of burnt *sulphur*, also was encreased about two drachms, but found unchanged in the least, either in colour, taste, or sponginess.

‘ I afterwards placed it in the focus of a burning-glass, but could neither make it take fire, nor melt it; only it boiled, and gave forth a smell of *aqua fortis*: after leaving it in the fire so long, ’till it fumed no more, I found it decreased almost an half, and what remained appeared black, shining, flaky, insipid, and in no manner altered by the burning-glass.’ (This is, certainly, a circumstance that merits great notice, in particular, that it should refuse to yield to one of the most quick and violent fires of vitrification in nature, namely, that of the sun.)

‘ Now, this matter I suppose to be the earthy part of common *sulphur*. I weighed it, and found it to be one ounce, and almost one drachm, that is, about $\frac{1}{4}$ of the whole:’ (that is, of four ounces of *sulphur*.)

‘ Now, as I could not force it by the burning-glass alone, and *per se*; upon adding a little borax, it melted to a glass of a grey-brown colour: this glass, after standing for some time in a moist place, I found, at last, strike a grey-green efflorescence all around; whence I learn, the *sulphur* employed in this process, to have held some copper, but in so small a quantity, as to be inseparable from it in a metallic form.’

‘ The fume still forced out by the burning glass, is, in all appearance, the remains of the fatty earth and acid salt of common *sulphur*, which the common fire could not force out. I apprehend this fume to have contained as much oily matter as acid salt; consequently, in this *caput mortuum*, to be about three drachms of salt more, which, with

' with the three drachms and sixteen grains above,
' make six drachms, that is, $\frac{1}{2}$ in four ounces of
' flowers of *sulphur*, &c.'

This account our author [M. Homberg] has spun out to a still greater length; but as what remains behind does not relate to the history, but his reflections and thoughts thereon, I shall only extract a couple of articles from it, and illustrate these, and some of the foregoing, with some remarks.

In the first place, 'tis not the true method of analysing a subject into its essential parts, to make use of *additions*, that may afford any suspicion of closer mixtions, and new inseparable educctions. *Sulphur* and oil are so nearly allied to each other, that nothing can be more so. What can we suppose to be in oil, proper for making separations? And how indifferently too does the separation come out, especially when we consider the remaining black, unvitrifiable earth?

(2.) Is it also certain, that the assigned sixth part of acid salt was all of it derived only from the sulphur; and may not the vegetable acid, such as may be plainly shewn to be in oils, contribute something also, and how much?

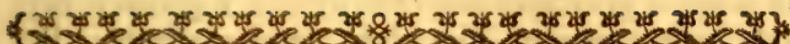
(3.) The three last drachms, separated from the remainder by the burning-glass, our author only suspects to be an acid salt of *sulphur*, he cannot prove it, like that gone over in the distillation.

(4.) Doubtless, the oil has also left behind it not a little of a coaly earth; how then can all the matter remaining over be ascribed to the *sulphur*?

Nay, how can the half, or a fourth only ; seeing oils *per se* contain not a little earth, and more than a little oil was employed in this process ; on the contrary, the *sulphur* consists least of all in an earth, but almost entirely in the acid salt ?

(5.) Are all greens the effect of a copper ? Does not alcali with acid, also with *sulphur*, make a green ? Though I allow *sulphur* a copper-earth, which is only to be shewn with sal-ammoniac, or spirit of urine.

(6.) Has he sufficiently reflected, when he expresses his surprize at the quantity of the water gone over, and which he might also have easily supposed in oils, that in the explicit enumeration he above makes of the principles of the *sulphur*, he has there left it quite out, and would here reckon it for one ? For the rest, this experiment is so far ingenious, that not only a large quantity of acid salt is educed, but an extraordinary proportion to its quantity in the *sulphur* ; and it is no small commendation to M. Homberg, that he has shewn so much diligence in the examination of natural bodies, and discovered such a number of truths, that we scarce find many to have equalled him in this respect.



C H A P. X.

Of the ARSENIC in the PYRITES.

WE are here distinctly and orderly to shew, whence *arsenic* proceeds, what it is, and what analogy it bears to other bodies; it being a dangerous subject, few are very fond of entering into an intimate familiarity with it; for which reason, it is a matter hitherto but little understood.

Arsenic, in its proper, entire form and colour, greatly resembles a white metal, nay, almost its own ore, *mispickel*, also *cobald*; but in its texture, its relation to the fire, air, and hammer, we soon find it differ considerably from the nature of genuine metals, nay, something from that of the semi-metals: and I know not whether I should allow it to have something more, or something less than these.

In itself it melts in the fire, not as a metal usually does; nay, not even as a bismuth or regulus, unless something fixing, as iron, be added to it, without which it begins directly to fume, and so flies entirely off. Thus it is fugitive; but in close vessels returns again to its pristine metallic form; nay, though regulated by means of iron, not a little of which goes to make up the regulus, yet, by a gentle roasting, it not only separates again from the iron, but, by sublimation, recovers its former state. Under the hammer it manifests a great degree

degree of brittleness, and hence evidently appears to want a principal characteristic of a genuine metal; nay, it is not, like zink, semi-malleable, but quite brittle, like a bismuth and regulus.

In the air it becomes black all over externally, whereas fresh out of the retort, at least for the most part, it is of a shining bright, like a mirror; and each fresh fragment or shiver of it, broken in the morning, has a black skin upon it by night; so considerable is the ingress of the air into this, that the like is not known in any other metalliform body, either bismuth, or regulus. It is further remarkable, that some genuine, though imperfect metals, as iron, copper, and lead, are more obnoxious to the action of the air than these last, as appears by the rust, verdigrease, and ceruse, they severally yield. In a word, *arsenic*, in its genuine form, is a semi-metal, a middle metal, and a fugitive metal.

But *arsenic* is, in this semi-metallic form, least of all known, appearing not so often therein, as in other forms; and thus I am obliged to describe it in every disguise it wears, both as exhibited by nature, and the various processes of art.

Arsenic appears either in a reguline, a powdery, or a glassy form; or as mineralised, or reduced to an ore-state, a flaggy and stoney body. In a reguline form, it is found either sublimed, and forced off, or as if cast in a cone, like glass of antimony.

Of the sublimed I have spoken above, and must still add; first, that thus it is extremely flakey, light, and porous, and unlike any other smelted reguline

reguline body; again, that it then discovers something very peculiar, and worth noticing, particularly, its easy receptivity of the action of the air, and of the smutting or blackness thence arising, which is observable of no other metallic body whatever. Moreover, from this smutting by the air, we may probably infer, if not the formal presence, yet the production of the fatty, inflammable matter; since this blackness is equally as fuliginous, or sooty, as that generally in the sublimation from the *white pyrites*, preceding, and sometimes partly accompanying this volatile *arsenic* regulus; yet there to be considered, not so much a part of the regulus, as of the *pyrites*. Now, whether this smut or blackness be an actual sulphur, and thus not its inflammable part alone, is not so easy to determine, as it cannot be separated, and brought to any test; yet the first is the more probable opinion.

As (1.) the fuliginous form shews, if not a total resolution, yet a superficial corrosion, rather than a new production; and yet this last should here seem to be the case, as neither in the subject alone, the *arsenic*, nor in the agent alone, the *air*, a genuine formal sulphur can be exhibited: and further, as white *arsenic* itself may, by the addition of only an inflammable, not a sulphureous matter, become, after a new sublimation, smutted again. Now, in this form *arsenic* is denominated *fly-stone*, *fly-poison*; in regard flies, and the like insects, are by its means destroyed; though the above black powder be fitter for the purpose, as, on the score of its tenderness and porosity, it is more communicable of its virtue to the water tempered therewith: and the appellation, *stone*, has been borrowed from the fossil, or native *fly-stone*, which is a real

a real stone, or ore, and put to the like use; tho' the sublimed neither shews like, nor contains any thing referable to the nature of a stone. And here the difference between native and factitious *fly-stone* is carefully to be observed, which you have, when the experiments exhibited therewith happen not to coincide; in regard the native, on the score of its incidental admixture, proves, at times, to be something different.

In a powdery form *arsenic* is of such a degree of tenderness, or subtlety, as therein not to be exceeded by the most impalpable powders; and of different colours, as, black, yellowish, grey, and white; yet, most frequently, of the white grey. When it appears white, like a beautiful meal, or flour, which happens to it in the fining, it proves right pure; and by how much the whiter, so much the less is it fullied with foreign admixture; if grey, it contains something of a footy, inflammable, nay, a metallic earth; as appears from the grey *poison-meal*, often collected from the vents of the tall furnace, with some lead, and a little silver amongst it; if black, it contains still more of such a coaly earth, to which colour it never arrives in a large and open, but only in a clofe, small, and sudden or brisk fire; if yellowish, which colour commonly runs to an orange, it has then some sulphur along with it.

These various incidental colours proceed chiefly from the incidental ores along with it, as well in regard to these ores themselves, as their various admixtures, which may be either accidental, or procured by design: where, for instance, the sulphur, when lodged in an ore, and rising together with the arsenic, must needs make it of an
orange

orange colour. Yet, the kind of the fire and furnace, where the ore comes to be treated, is, in this case, certainly, of great consequence, not only as to the production of the several colours of the *arsenic-meal* (the sooty matter either burning away and dissipating, or remaining therewith; the sulphur either softly retiring apart, or being hurried or laid hold of by the *arsenic*) but also as to the corporal form, in which it appears: for instance, the *poison-pyrites* yields, indeed, in the open air, a mealy, commonly a grey powdery *arsenic*, but in close vessels appears of a flakey, reguline form. Thus, it is one thing to *drive* or force it off in retorts, subliming vessels, and the like, where the ore is out of the contact of the fire, and where the *arsenic* acquires its proper reguline form; another thing, to force it off in *roasting furnaces*, as is done at the cobald and tin huts, on occasion of roasting the cobald and tin ores, where, by means of the adjoining wind-furnace, the actual flame, and fatty particles of the fire, play over and through the ore. The case proves yet different, in smelting furnaces, where not only the flame of the coals, but also the fatty, and at last the alcalised coals themselves, exert their efficacy on the ore; besides, the force of the blast volatilising and carrying off along with the *arsenic*, not only crude earthy particles out of the ore, brought to the highest degree of activity by the strong glow, but also metallic particles themselves, as coppery, leady, and silvery. Lastly, there is a further difference in open roasting hearths, where the ore is not only exposed to the immediate contact of the flame and coals, but to the actual influx of the air, weather, and rain; whence we are enabled to observe in fume-powders, that variety of colours, as, white, grey, and yellow, which, under covered and close furnaces, does not so easily happen.

Now

Now where it cannot thus, on account of the reasons mentioned, arrive to its proper semi-metallic form, but, according to the particular method of operation, happens to be dispersed, it proves no other than an earth, an ash, or a calx of a metallic body, whose metalleity may be destroyed, and again restored.

Thus it rises in the operation of roasting in the tall furnaces, and copper-furnaces, and settles wheresoever it finds the first cool and quiet retreat; in the tall furnaces, indeed, it seeks the highest; and where the air has once taken due hold of it, it is thereby dissipated to a considerable distance; and this, at the mines and huts, is called *but-fume*; however, this, which is a pure arsenic meal, is not to be confounded with calamy, though they are not unlike in colour; but the former settles lower down, whereas the other is by the fire driven much higher up.

Arsenic also lodges in zink and calamy flowers, in sublimates and *cadmia fornacum*, though in a very small quantity: these are either entirely powdery, or in tolerably compact lumps and masses, neither firm nor hard, but tender and crumbly, and easily pulverable, though in themselves not a powder, but naturally like a baked earth. Their colour is commonly a dark-grey underneath, over that a whitish grey, and the uppermost of all a yellowish white; their particles are generally quite clear, or flakey, like a tender glimmer; their texture very porous, spongey, and loose, consequently are extreamly light; to the touch they feel rough, stubborn, and gritty, though rubbed to a tolerably fine powder.

They

They are generally, though falsely, considered as a proper *but fume*, or *arsenic*, especially when they assume appearances of a grey meal: but, not to insist that experience shews quite the contrary, we may easily imagine, volatile matters, that should stand and hold out, when settled in the confines of the strongest glow of a furnace, to be something else than *arsenical*; and hence we need not wonder, they destroy neither mice, nor rats.

This zinky matter manifests itself in tall smelting furnaces, particularly in those where the operation of *crude smelting* is performed; that is, where small or poor ores, which are commonly quartzy, mock-lead, and *pyrity*, also, incidentally, somewhat *glittery*, are smelted and concentrated from a large quantity of ore, to a *regulus*, or cake. It takes its place in the lower parts of the furnace, particularly on the sides, having under it, for its stool, that mock-lead, stoney, and hard matter, of which hereafter.

The manner of its origination must, doubtless, be like that of *arsenic*, namely, in the way of a fume and vapour, seeing no part of it is observed to be run. When exposed long to the air and weather, it opens, that is, becomes tender and porous, and fit for making brass; the reasons of which are not proper here to be given, as I now only consider it on account of its *arsenic*. At our huts it is thrown away, and as it must be knocked and broke off the furnace, 'tis called *furnace-fragments*, by many *calamy*, though improperly, on account of its very different admixture; wherefore that appellation ought to be qualified by the epithet *calamy-furnace-fragment*, or *furnace-calamy*; nay, it should justly be

be limited, especially if we would not confound it with that I am now to speak of, and from which it differs not a little. But, as is already said, it contains the least *arsenic* possible, discoverable upon roasting it, rather by the nose than by the eye; but it partakes of sulphur in a greater proportion, as appears also from the roasting, and as may easily be conjectured from the ground-mixtion of this zinky matter. In a word, it smells partly *arsenical*, partly sulphureous; as sulphur may, intangled in such calamy admixtures, resist the hottest glow, so much more may *arsenic*, which commonly yields not so easily to the fire as sulphur does.

Underneath, and behind this, there lies, lower on the sides of the furnace, a stoney, hard, heavy, black matter, not properly to be classed for its *arsenic*, but rather, on account of its order of place. Many a one might take it for a flag, or scoria, than which it is nothing less, as appears upon breaking it; seeing it does not appear glassy, smooth, and shining, as genuine flag does. Externally this matter is often, as it were, glazed over, but internally has a quite different appearance, namely, that, notwithstanding its hardness, which indeed, in respect of the abovementioned calamy-furnace-fragment, is considerable, yet it may be ground small, so as to become like a footy dust to smut the hands, which flag never does, unless reduced, in the most careful manner, to the finest meal. Here and there, internally, it also often appears *flaggy*, and run; nor can it be otherwise, considering the stoney nature of the ores employed in the crude-smelting, and the fierceness of the fire. This effete matter contains but little *arsenic*; but taking of what is glittering, and in texture often

often appearing like a fine-grained mock-lead, we shall find reason to class it amongst arsenics ; nay, sometimes it shews so like a fossile mock-lead, and a mineralised body, as to impose on the most intelligent in ores. The origination of this, indeed, rather than of the preceding *calamy* matter, seems to be owing to a caking or running together ; yet it is also of various sorts, and, upon properly viewing many a sample of it, we must allow it rather to be aggregated together in the way of a damp, or vapour. For, though we find amongst it pieces, not only caked together, but quite vitrified, as may be easily conjectured from the running together of quartzy, especially if somewhat leady, and thus possessed of vitrifying particles, yet the principal part is of quite another, or rather a new appearance.

It appears black and grey, flakey, and almost like a mock-lead, though very different, it being more kindly and light. It is not only, in some measure, of the nature of zink, or calamy, which cannot be said of any one sort of mock-lead, but contains as much, if not more *arsenic* than the meagre, lean mock lead. In a word, 'tis a kind of fly-stone sublimate, rising up entirely at the last, but to no very great height ; which, together with its calamy and *arsenical*, or, volatile portion, has taken along with it, by the violence of the fire, something of a crude, earthy, and, perhaps also, of a mock-leady nature, whence it happens to consist of so coarse a mixture, as to be uncapable of mounting high ; and this is simply called *furnace-fragment*, as it must be broke off, in order to clear and fit the furnace for a new operation ; a name which may sufficiently distinguish it from the abovementioned grey, white, yellowish

N. matter,

matter, if, for the greater perspicuity still, be added the epithets, *coarse*, *mock-leady*, and *poor*.

Now in smelting-furnaces, where the *arsenical* matter skims off, or rather evaporates from the metal designed to be procured, I know of nothing else, which, as an *arsenic* form, should here deserve a place; all to be found there, and referable hither, being either *poison-meal* and *but-fume*, or *poison-stone*, that is, *furnace-fragment*. For the external images appearing in many places in clusters, or flakes, and the like beautiful confections on this and the other *furnace-fragment*, according to the descriptions of the ancients, and bare copyings of the moderns, are very rare with us at Friberg, nay, they are not at all observable, and are, properly, something procurable rather from actual calamity-works, than from ore-smeltings, seeing they appear in all manner of zinky flowers, and the like efflorescences, in the course of *brafs-making*.

We are not, however, to suppose arsenic, like sulphur, to be entirely dissipated in roasting-hearths, and in furnaces, for more than a little of it fluxes in a metallic form along with any thing capable of retaining it; settling together with the metal, as in a regulus, in the fore hearth; bearing the being tapped off therewith; not mingling, 'tis true, with the metal, but parting from it, floating a-top, and bearing, after cooling a little, to be heaved off from it, like a cake. Yet, in the method of crude-working we observe, that what of it remains unvolatilised, goes into that regulus usually called *crude-stone*, without being able to appear in the above separated form; because the metal, whether lead or copper, which should, and does repel it, is not yet arrived to its due metallic body, but is still greatly

greatly intermixed with all manner of earthy foreign matters, consequently, is of a very loose, spongey texture, and hence as light, if not lighter, than arsenic itself; and that matter, wherein it principally fixes, not yet separated from the said metals.

But in the methods of *lead-working* and *black-copper-making*, it plainly appears in our smeltings, where *arsenical* ores come into the *additions*, and where *arsenic-pyrites* happen in the *crude-working*, and the *crude-stone* being, at length, duly prepared, comes into the *lead-working*, and where the copper-stone being *set*, or drawn off, comes into the *copper-working*; nay, is there the whole, or principal part, when the *lead-working* happens to employ no pure *glitter*, or *lead-ore*, but is intermixed with all manner of rich, chiefly *arsenical*, ores, also with actual unseparable cobaldish ores: in a word, where many sorts come together, and one working succeeds another, 'tis no wonder, if, in many places, little or no mention be found made of *speise*, *leg* *, &c.

What thus retains the *arsenic* to itself, and, in some measure at least, fixes it, so as to make it flow like a metal, and bear the being cast, is, principally, an iron-earth. I say *principally*, and this not only at our lead, but at our black-copper-workings; though particularly in these last, some admixture of copper must be allowed; and this, sometimes, is called *speise*, especially, when produced from the *lead-working*; sometimes *leg*, also *kupffer-leg*, when from the *copper-working*; it floating

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and

* These are the several appellations of the abovementioned floating *arsenical regulus*.

and lying a-top the tapped black-copper, and from white inclining a small matter to a copper reddish cast. Both are of a whitish metallic appearance, texture, and weight, but brittle; moreover, tolerably hard, according as they are more or less incorporated with metallic earth; both contain from a third to a half of arsenic, and, as I have experienced myself, may also hold a good deal more, but seldom less; and that from incidental circumstances, which, in the busines of smelting, both in regard to the method of working, and to the matters themselves, may be endlessly variable.

Speise is a term used also among workers in brass, but with the addition *glocken*, thus denoting bell-metal; a matter appearing pretty pale, though inclining more to a yellowish cast, as it must, on account of its principal ingredient, the brass: as to the rest, it is harder, and more metallic than, and therefore not to be confounded with, our *but-speise*. Assayers also have their *speise*, but which they might more properly call an iron-regulus; as yielded by those *pyrites* which contain no copper, and remains further unexamined by them, seeing they look for nothing else in *pyrites*, but silver and copper, consequently is unknown to, and thrown away by them, under an appellation borrowed from some colour or other, and which, in some measure, serves as a screen for their ignorance. Now, 'tis true, there are some *pyrites*, whose iron-earth is *arsenicated*, as the white, entirely; many of the yellowish, considerably; and thus, in assaying, there arise such *reguli*, as assay-ers may, on the same foot with smelters, call *speise*; but as some of them afford only a very small matter of, or no arsenic at all, 'tis wrong to bring them under one common appellation, *speise*.

In

In the *arsenic-butts*, which are chambers where the *arsenic* is refined and purified, *arsenic* again exhibits the appearance of a fine meal, or of a crystalline body; both ways, sometimes of a white, sometimes of a yellow, sometimes of an orange cast: yet it ought not to be distinguished so much by being a meal, or powder, and a fluxed body, as by the variety of its colours; for the powder is convertible to a crystalline body, and this last may be reduced again by a heedful sublimation, to a meal, and the meal again converted to fly-stone. Now, as the meal, either yellow or white, turns mostly, nay, wholly to a crystalline body, we shall here the rather treat of the crystalline form of *arsenic*; and as the yellow and orange colours remarkably differ from the white, we must say something to three sorts of *arsenics*, namely, *white*, *yellow*, and *red*.

Arsenicum crystallinum album, white crystalline *arsenic*, is a white, considerably ponderous, fluxed, glassy, transparent body, brought to that form by means of pot-ash and sublimation. The pot-ash principally serves for purifying, or for, at least, retaining and consuming that fuliginous matter lodged in the *arsenic*, and which makes it of a greyish cast; be such matter only from an inflammable earth, or, as it also sometimes happens, from sulphur itself. Whether it have any other effect thereon, must be learned from a careful examination, made expressly, both of this crystalline *arsenic*, and the crude *arsenic-meal*, and from a candid comparison of the several proofs made, the separate consideration of which would here carry me too far.

In order, however, to discover the genuine proper nature of this smutting substance, I have, as supposing it to be a fat, inflammable earth, digested the white crystalline *arsenic*, after rubbing it fine, along with inflammable matters, as expressed oil of almonds, and by sublimation procured a quite dark-grey sublimate. Again, treating it in the same manner with iron-filings, by this means, along with some white crystalline flowers, I have obtained a dark-grey *arsenic*; so that the black matter arising along with the *arsenic* from *arsenical pyrites*, is to be ascribed to an iron-earth; especially as it is otherwise evident, that no *arsenical pyrites* is without it.

I also found quicksilver alone capable of withholding this blackness, and also the yellowness of yellow *arsenic*, and of raising the *arsenic* alone in beautiful white crystals; a circumstance, sure, worth no small degree of attention. It is pretty heavy, nay, to a degree of making it suspected of containing something metallic, even should it be unknown in its native form; it is partly transparent as glass, partly of a milky colour; and what was transparent, in time, loses that quality, becoming externally, also, of a milky colour, particularly by means of the free access of the moist air; nevertheless, it continues sparkling or shining, and, against the light, if newly broke, with its shivers, appears smooth, and internally transparent; but, by degrees, it loses all its transparency, and that sooner or later, according to the size of the pieces or shivers, and the nature of the place they are in; 'till at last, still retaining its splendor, and without falling, or turning to a powder, it becomes throughout of as milky a colour

lour as a white smalt, usually employed in enamelling; and, to my mind, almost such another mass as that arising from running alum and common salt together, for the preparation of Glauber's salt.

Whether it be a real salt, I shall as little dispute as believe, seeing it does not partake of the genuine properties of a salt, being neither soluble in water, nor peculiarly affecting the tongue: the truest conception we can form thereof, consists in considering it a calcined metallic body; as, in its origin, it exhibits a metallic body, which is here only a little disguised, but again recoverable upon the addition of the metallic portion, which happened to be burnt out. In the course of the refining, it rises like a white fume, and settles, at first, as a white powder, which, as the heat gradually increases, 'till the subliming vessel be made of a thorough glow, cakes and runs to a close, glassy body.

Arsenicum crystallinum flavum, yellow crystalline arsenic, is, in its principles, nothing else but the above white sort, and in the very same manner brought to that form; only that some sulphur happens to stain its beautiful milky colour with a cast of yellow; and though, properly, not so transparent as a fresh white sort, yet, in its substance, it is shining and glassy, like a yellow smalt, or enamel, though by far more beautiful.

Arsenicum rubrum, red arsenic, differs from the yellow only in being more richly dosed with sulphur, and, consequently, has a greater degree of opacity, and a less glassy appearance; for the rest, 'tis an arsenic in ground, and popularly called san-

darach; yet, under a proper encheiresis, or treatment, it often turns out as beautifully transparent as any ruby, only its redness inclines more to an orange, whence it is sometimes called *sulphur-ruby**. If it degenerates to a brown-red, it has either stood too long in the fire, or got some foreign admixture along with it, either by accident, or with design, as may be seen from the *lapis de tribus*, where the metallic, antimonial portion must needs sully it; yet this brown-red tint is often no impediment to its transparency, when held to the light in thin pieces.

It is brought over, like sulphur, by a distillation, from retorts into receivers, rather than by a sublimation, and this is the very reason of its opacity; for, if you force off only a little of it again in a glass body by a strong sand-heat, so as to melt in the neck, it runs down in clear drops, appearing like a red glass. It is certain, *arsenic* greatly affects the sulphur found here, and must therefore impart the colour; and no way has hitherto been hit on, I will not say, of separating it entirely, which is impossible, but of separating even the greatest part of it; and yet some of it must go off, partly of itself, by the softest degree of fire, for sulphur mounts easier than *arsenic*, though this succeeds not with the yellow crystalline *arsenic*; partly through the addition of a separating medium, or matter, which sulphur more affects, for instance, quicksilver: when the *arsenic* happens to rise white separately, and settle higher up, the quicksilver, which cannot rise so high, settling lower down, as a grey sublimate along with the sulphur,

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* *Rubinus sulphuris, item, rubinus arsenici.*

Moreover, as sulphur appropriates the quicksilver to itself, and quits the *arsenic*, so it keeps in a juster proportion with the former, than with the latter; it, in one case, bearing more and less, almost in the proportion of the dose given, whatever that be; and in the other, being incapable of receiving either more or less, the proportion being constant, a circumstance worthy of notice.

Red *arsenic*, or *sandarach*, may be made from pure ore, and such *pyrites* alone, wherein the sulphur and arsenic are together in a sufficient quantity; or from *pyrites-additions*, or dosings, so that the one shall supply what the other wants; or from poison-meal and *sulphur-pyrites*; or from *arsenical-pyrites* and sulphur-slags, that is, the *arsenical* sulphureous residue procured from crude sulphur: but the attempting to make it from white crystalline *arsenic* and actual sulphur, either does not succeed at all, or with great difficulty: whence appears, (1.) the somewhat coy or repelling nature of the white crystalline *arsenic*; (2.) how much the chemical combinations depend on the appropriations, congruencies, or aptitudes, also on the diversity of the matters, when employed in their unprepared and native state, directly from their matrices and natural admixtures; so that red *arsenic* is not a thing, in its ground-substance or principles, distinguishable from the white, as some falsely imagine.

Thus we have exhibited *arsenic* in all its various appearances, from its first fly-stone state, to that wherein 'tis fitted for common use, and thus from the huts to the shops: and not only so, but we here teach how to reduce it back again to all the forms it had before undergone; in particular, to its

first, native, reguline, semi-metallic state, so as to prove more beautiful than it originally was; as thus: take finely pounded white crystalline *arsenic*, and mix it, either with the black flux, or with salt-petre and tartar, in the usual manner of making regulus of antimony, and letting it duly run in the wind-furnace, you then procure a compleat, beautiful regulus of *arsenic*; yet, little or none at all, if either you let the crucible stand too long, or give too brisk a fire: but if you miscarry in this, take iron in aid, and proceed in the usual method of preparing the martial regulus of antimony, and the *arsenic* will be sufficiently fixed. Only, by this last method it proves impure, from having swallowed up a great deal of iron, as appears from the analysis; it is, however, the greatest part *arsenic*, which may easily again be made to fume from it. It generally appears like a *speise*, with which it also greatly agrees, and, upon adding some copper to it, it turns of a reddish cast, nay, becomes the very *mixtion* of the above described *kupffer-leg*, nay, even *kupffer-nickel*.

I shall further only suggest, that *but-fume* corrodes the very window-panes of the huts, turning them of a milk-colour, and rendering them dim and opake, and thus it finds, as it were, a magnet in them. Again, that with lead it vitrifies exceedingly easy; and the glas thus procured proves extremely useful in *incottions*, as it forces stubborn and unkindly ores, with this circumstance attending, that this highest of combinations, which is even performable in close vessels, is an uncommon and almost incredible instance in the busness of vitrification: and this, in my opinion, affords, if not the principal, yet not the least considerable reason, why *misspickel*, when its *arsenic*, in the operation of

crude-

crude-working, happens to corrode, vitrify, and thus easily carry off the lead among the scoriæ, at least from the *glitter-eyes* always intermixed, is considered as rapacious and unkindly.

To recapitulate briefly; *arsenic*, by means of art, shews itself either a volatile, flakey, semi-metallic, or a reguline body, which is a factitious *fly-stone*; or a grey, white, and yellow powder, and then it is called *but-fume*; or a *furnace-fragment* (*cadmia fornacum*); or a *speise*, or a kind of glassy body, and then 'tis a white and yellow crystalline *arsenic*; or a red *arsenic*, that is, *sandarach*; or again, a semi-metal, and a *regulus*.

Here I must not omit explicitly mentioning a matter I only incidentally touched on above, as being, in some cases, entangled with *arsenic*, and this is *zink*, which lodges both in fossile and factitious calamys.

Zink, or *spelter*, cannot better be described or conceived than by saying, that it is that matter which makes or tinges copper yellow, an effect to be affirmed of no other thing in nature besides. *Zink*, so far as is hitherto known, is, principally, in three forms; (1.) in that semi-metallic, reguline form, properly called *zink*, or *spelter*; (2.) in an earthy, or rather stoney form, namely, in the fossile calamy, or *lapis calaminaris*; (3.) in flowers and sublimates, in particular, in the above described white-yellowish tender *furnace-fragments*. Genuine formal *zink*, also called *contrefait*, is a semi-metal, externally like lead, yet something brighter, internally shining like a mirror; not very brittle, like a bismuth or *regulus*, and yet not very malleable; altogether as inflammable as a sulphur, when it changes . . .

changes to a white spongy froth and wool, a *philosophical cotton.*

It turns copper not only of a higher yellow, whence the metal happens to be distinguished by the appellation, *prince's-metal*, or rather *bronze-metal*, at least with us Germans, but it also renders it more brittle than the fossil calamy does; hence, I suppose the proper tinging substance, which in the fossile calamy is blended with an earth, something adventitious and foreign, not entering along with the tinging parts into the body of the metal, is incorporated in another metallic brittle-making substance, namely, lead.

For, (1.) the sort of ore at the Hartz, whence our *zink* is derived, is never without lead-ore, nay, is principally found to consist therein; (2.) from fossile calamy (for which end I have employed the Spanish) and *lead-glitter*, I have produced a formal beautiful *zink*, which, in any other method, would not succeed, at least not with me. Nay, it is no uncommon thing to find calamy and *leadglitter* together in a vein, a sample of which I can shew from Brilon in Westphalia: and it will be plain from considering but a little attentively, the loamy earth near Ulkos in Poland, wherein lead-ore lies irregularly huddled together, to which might be added other circumstances; that there is something separable from the *zink*, which is not indeed pure lead, tho' approaching nearer to lead than to *zink*.

As I am perswaded that this tinging substance is lodged in other earths and stones, besides that called calamy, at the brass-huts, so there are also other metals, besides lead, out of which it may be educed; at least I have found, upon working tin along with

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a certain ore, without any the least addition of calamy, if not a real corporal zink, yet its proximate infallible sign, the genuine *philosophical wool*. But without any such experience, and from a slight knowledge of metallic bodies, the derivation from lead to tin is easy ; but then in the fire this production is extremely dissipable, zink burning away as quickly as it is produced, so that it is not procurable in our huts in its living state ; not from a defect of the proper matter for the purpose, as we may have such in *furnace-fragments* ; but then it is no longer to be catched living (from the following circumstances, namely, the degree of the fire, the nature of the furnaces and *additions*, and the inexperience of the operator) but dead, and in its ashes, from which, indeed, it is again recoverable *.

Formal zink, fossil calamy, and *furnace-fragments*, or *cadmia fornacum*, appearing so different bodies, who could imagine these three should be possessed
of

* Pott, in his dissertation on zink, makes zink to arise from the metallisation of an alkaline earth, whence he deduces its solubility in acids, and that it consists of a mercurial, vitrescible, and a tender inflammable earth ; the mercurial earth appearing from its flowing in the fire, its commixtion with mercury, and its mercurification ; the inflammable earth, from its ready ascension, when treated *per se* in the fire, as also from its fulmination with nitre ; its vitrescible earth, from its vitrescency, which Henckel first accomplished in the vehement heat of a wind-furnace. But its specific nature, and mixtion, he makes to consist principally in the indeterminable, and scarce perfectly imitable combination of a copious inflammable principle, along with a certain peculiarly alcaline earth : and to this earth is owing both its difficulty of vitrescency (such as is also observable in tin) superable only by a most vehement degree of fire, and the usual bitterness of calcareous earths in solutions ; and if, by means of the inflammable earth, it changes to a reguline body, is the cause also why copper changes to a yellow colour.

of one and the same virtue, or have one and the same *materia prima*, to tinge copper withal! or, who could think it possible to educe such a matter from tin, without any addition of calamy, zink, and *cadmia fornacum*? Here I cannot omit transcribing Lohneis's * account, a considerable metallurgist of the *Hartz*, from which place alone zink comes to us: and though we might expect from him the best account of it, yet it happens to be concise enough, and something fuller and more explicit, both on the origin of zink, and on the *Rammelberg* ores, fit for the purpose, were to be wished for.

' In the course of the smelting, (says ' he) a sort of metal, there called zink, or *Contre-
fait*, collects below in the chinks of the fore-wall, ' or breast of the furnace, where not covered thick ' over, between the shiver, or slate, of which it is ' built. Upon knocking on the wall, this metal, ' which is white, like tin, yet harder, and more ' malleable, and tingling like a little bell, runs out ' into a trough placed underneath. The quantity ' procured at a time is in proportion to the care ' employed in collecting it. They sometimes get ' to the quantity of two pounds, at other times, ' not quite three or four loths.'

Fossile calamy, *lapis calaminaris*, called also *cadmia fossilis*; under which last appellation we must not include the *cadmia* called *cobald*, yielding smalt; and which by way of distinction, both from that other *cadmia*, and other cobaldish, namely, arsenical ores, is called *cadmia pro cæruleo*. Calamy is a stone, or often a sort of stoney earth only, sometimes yellowish, sometimes brown, and sometimes a brown red; not only as it comes to us from other countries,

* Berg-buch, p. 83.

countries, as Poland, Hungary, Spain, and the Indies, but as it is also found in several parts of Germany, as Bohemia, Franconia, and Westphalia. The heavier it is, it imparts the more a greater increase in weight, and a higher tint to the copper. It affects a loamy, claeiy, fat bottom; and such earths have even properties, manifesting a no small degree of affinity with *calamy*; it therefore lies not very deep, its mother-earth appearing commonly just under the turf, nay, constituting the uppermost layer, as at Tscheren, near Commodau, in Bohemia, where it may be taken up at the day. This Bohemian sort yields (1.) an iron-vitriol, as an actual iron-stone also *breaks* amongst it; (2.) alum, a famous alum-work lying near the above place; and, I doubt not, but all *calamy-stone* in general do the like; but if you give it copper, a great part of the earth of the *calamy* incorporates with it, and assumes a metallic form and property; from hence it may be known, that brais, into which about a third of its earth is introduced, will endure the being worked like any fine copper.

Calamy furnace-fragment, or *cadmia fornacum*, I have already considered, so far as it included arsenical particles; but must here again take it up, because its nature and effects are entirely zinky.

Hither is chiefly referable what with us not only hangs in the upper parts of the furnace, but which also looks bright, particularly yellow and whitish, being tender, and not run together; also what settles externally over the fore-wall or breast of the furnaces, between the chinks or openings of the stone, and the whole of that lower, mock-leadey, flaggy, crude-stoney, caked matter, which, in the course of working the furnace, being still soft, is beat

beat out with an iron, and called *sweep*. From the lead-working, to which are taken, together with the *crude-stone*, and the *glitter-ores*, the burnt rich silver-ores, little or nothing is procured; as most ores, both the smallest or poorest sort, have, by the operation of crude-working, and the rich ores, by that of *roasting*, already lost their aptitude for, and virtue of yielding *zink*: besides, the *glittery* or lead-ores being, with us at Friburg, not in any considerable quantity, they cannot, without the evaporation of these last, exhibit those zinky flowers they might otherwise contribute to ripen.

Were I to pick out, among the many ores and minerals, that come into the operation of *crude-working*, those that contribute to form this zinky furnace-fragment, I would take the *glitter* and *pyrites* together; from the former I could derive the body, from the latter, the soul, and say, that the sulphur and lead are become incorporated and animated by a peculiar appropriation and aptitude, and a number of unimaginable incidents, such as easily happen in the large way of working, though not in the small way of proof.

What the nature of this furnace-fragment, or *cadmia fornacum*, at the smelting-houses of the Hartz, is, I know not; but referring the reader to Lohneis, shall only relate the success of an experiment tried on Friburg *cadmia-fornacum* for brass; for this purpose, I roasted, after rubbing, the calamy under the muffle very small, 'till it no longer smelt of *arsenic*: I took the sort that, being longest exposed to the air and weather, was become tender, or opened, as they speak at the huts, this being esteemed the best sort, though for what reason I cannot imagine. After being well roasted, I mixed it

it with coal-dust, in the same manner as is done at the brass-works for fossil calamy, and with this mixture I dosed the copper in the crucible, and by letting the whole flux, or run well together, procured a brass like any other brass, excepting that it is somewhat more brittle, though it may bear being drawn into wire as far as no 15.

Among this furnace-calamy, forwards in the chinks of the furnace, about and over its breast, there is a spongy, woolly, white powder, but in small quantity, usually called at our houses *but-nothing*, also simply, *nothing*, or *nihilum*, which is the very same I mentioned above under the class of calamy flowers, as somewhat indeed *zinky*, yet likewise a little *arsenical*, and to be distinguished from the proper *arsenic-meal*, called also *but-nothing*, which commonly mounts higher. The genuine *arsenical but-fume* is a noxious thing, not deserving the name of that innocent drying matter, used for the eyes. *Nothing*, or *nihilum*, is an appellation in use also among druggists and apothecaries; and the celebrated M. Lincke, apothecary at Leipsic, informs me, our modern *nihilum* in the shops is only a tender, fossil, white earth, or marl, *marga fossilis*; and such I myself have hitherto found it: so that it is highly necessary, on many accounts, druggists should be subject to a visitation and inspection, equally with, if not rather than, apothecaries, as the latter are always supplied by the former with their drugs. Further, this shop-*nihilum* appears to me to be a kind of calx, or lime; M. Erhard, of Memmingen, informing me, that some apothecaries in Suabia burn spad to a lime, and sell it in large quantities to the druggists of Nuremberg and Francfort, under the name *Nihilum*. *Nihilum*, or *nothing*, was, doubtless, formerly, among

druggists and physicians, only a calx, or flowers of burnt calamy-stone and zink, or the woolly, white, tender powder, arising and collected from the preparation of calamy or zink, for brass or bronze-metal, or barely with this intention, and thus quite free both from arsenic, or other foreign admixture; as Pomet, an author deserving more credit and commendation than most writers on natural history, has truly hinted. Hither again may be referred the abovementioned *nibilum* from smelting huts, after culling and thoroughly burning it, in order to purge it from the arsenic, though scarce equalling the other in tenderness and purity: yet neither are calamys, nor zink flowers, and a fossil marl, one and the same in nature and effects: nor again, are marls one and the same, as I once found a sort, sold for a *nibilum*, to be arsenical.

Pomet writes as follows: ‘*Pompholyx*, white calamys, white nothing, and ore-flowers, erroneously called metal-ash, is what adheres, in the course of smelting for brass, to the cover of the crucible, and the smelter’s forceps; for, it is certain, that neither bell-metal, nor the metal, nor the *potin* (a kind of brass whereof pots are often made) but brass alone, yield the genuine *nibilum*, though most writers have thought otherwise; there being naturally nothing besides brass, or yellow copper, that yields the white calamys, or *pompholyx*. But though *pompholyx* may be easily found, yet no one thing, either through the ignorance or negligence of apothecaries, is more unknown; in regard most of them are of the opinion, *pompholyx* and tutty, having one and the same virtue, may be substituted the one for the other. The most beautiful *pompholyx* comes from Holland; not that it is really a better sort, but only on account

‘ of

of its being collected in a cleaner manner. You must chuse that sort which is beautifully white and light, and will bear rubbing easily, and clean, &c. Bell-founders may, indeed, collect a little of it, but so very little, and besides, not very pure, that it scarce deserves notice. The bell-founder, by whom I saw *pompholyx* made, assured me, he never sold it but to particular persons, who came and begged a drachm of him, to put into wine, as a drink in a fever; at the same time averring it to be an infallible remedy in that case; but I never tried it, nor would I advise it to any body else, &c.'

Besides this *nibulum*, there is another form, wherein zink lies concealed, namely, *tutia*, an Arabic, at least an oriental term; the reason of which is as little understood, as why calamy-flowers come to be called *nil*. It might originally have denoted a kind of drying, astringent plant, as the plant *turbith*, the *spodium*, or ashes of bones and plants, have been denominated from minerals, having, in use and virtue, something in common with, or resembling such vegetable or animal parts. In like manner the term *tutia* was introduced into the mineral kingdom; and as we had this commodity originally from Alexandria, it was called *Alexandrina*, as it still is at this day, from what part soever it comes. This appellation, 'tis true, is unknown in our smelting-huts, and consequently does not cause that confusion we experience from the term *but-nothing*. Now though we are directed by all the writers on the subject to the brass huts, and workers in brass, yet I am at a loss to conceive how this *tutia* can differ from the *calamy nil*, as both of them arise in the making and smelting of brass. *Nil* is calamy-flowers and a white powder; *tutia* appears like dark-

grey shells and rinds, and is also derived from calamy, but in appearance they greatly differ, which must be owing to different circumstances and causes, of which I am entirely ignorant, and of which no explicit account is any where given. Here again, we give Pomet's description of the *tutia* the preference to that of any other writer.

' The *tutia*, says he, denominated *Alexandrina*, also *spodium Græcorum*, is a metallic species, ' formed like scales or gutters (or rather, happens ' to be so formed) of different sizes and thicknes- ' ses, internally even and smooth, but externally ' like a shagreen, being beset all round with grains ' of the size of pin-heads, whence it had the name ' *tutia botrytes*. The *tutia* sold in France comes ' from Germany' (also from Sweden, according to Lemery, in his dictionary of drugs) ' where it ' is prepared from brass. We must not imagine, notwithstanding its being affirmed by almost all ancient and modern writers, that *tutia* is derived ' from yellow copper, and arises at the same time ' with the *pompholyx*; this is false, the *tutia* ad- ' hering to the earthen cylinders, or rollers, sus- ' pended in brasiers furnaces, for the purpose of ' catching the fume of the metal, whence the *tutia* ' has its shell or gutter-like form, and some of the ' pieces have earth still sticking to them. ' Tis ex- ' ternally of a beautiful mouse colour, and inter- ' nally of a white yellowish cast, not easily broke ' to pieces', &c.

Here we have the form of our *tutia* plainly enough described, only the reader is not to stumble at our author's making a distinction between brass and yellow copper, and allowing the *tutia* to be derived from the former, and not from the latter; whereas bras and yellow

yellow copper are, with us, held to be one and the same thing, but among the French, the latter is made from formal zink, and such yields no tutia; and as there is but little of it prepared, there must be but little demand for it: nor, at our author's saying, that *the tutia arises not at the same time with the pompholyx*; for, be this as it will, the tutia is derived from the very same principles with the pompholyx, namely, calamy, and tinges copper yellow. In short, *tutia, nibilum, cadmia fornacum, fossile calamy*, and formal zink itself, agree entirely in principles, though they differ in form and accidental appearance.

This digression from *arsenic* to zink, cannot be thought displeasing to the reader, seeing they are the effect of one operation, and, consequently, have an affinity with each other; and, upon rightly taking the matter, the *pyrites*, either from its sulphur or *arsenic*, assists to the production of zink: nay, it may be queried, whether, as Charras pretended, a zink may not be made from *arsenic*. Besides, I wanted to clear up a set of names, sometimes applied to one thing, sometimes to another.

Arsenic, orpiment, realgar, and sandaraca, stand for things, which if not entirely arsenical, generally partake considerably of it. *Orpiment* is a sulphur-yellow, flakey, *arsenical* mineral, of which painters, with the aid of indigo, usually compose a green. *Realgar* is an unknown term, with some denoting the same thing as *arsenicum crystallinum flavum*; with others, *arsenicum rubrum*, or the common sandarach; yet it always means something in which the *arsenic* is the principal part, and the sulphur, which, in both the red and yellow, makes

the distinction, is, in the former, somewhat more, and in the latter, somewhat less in quantity. *Sandaraca*, properly denoting a gum, or rosin, is here also applied to a mineral, which is, or appears to be gummy, or fatty. Now, 'tis true, genuine sulphur is of such a nature and form, but by it this last is not meant, but something arsenical, only combined with sulphur; and, in short, such a body as, be it white, yellow, or red *arsenic*, may, both by a lixivial and acid salt, (which is something very extraordinary) in particular by spirit of nitre, be changed into a formal gum.

We are, in the next place, to enquire into the origin of *arsenic*, or whence it is derived. And (1.) 'tis found in the earth so pure and snow-white, as scarce to be rendered more so by art; but this is a very rare case. So far as I have been able to judge from circumstances, it may lie unobserved by coarse veins, consisting of *pyrites*, *mispickel*, *mock-lead*, and *glitter*; yet the *arsenic-pyrites* commonly, and in large quantities, breaks among them, and chiefly contains the *arsenic*. At Friburg we know nothing of this *arsenic*, the samples I have either seen, or actually had in my possession, being only from the mines of Joachimsthal, in Bohemia, where the veins consist, together with *red-goldish* ore, both of the *smalt-cobald*, and that other black *arsenic-ore*, of which more by and by, usually called *cobald*, but really a kind of pure fly-stone, or sooty *arsenic*.

Whether this white, fossile *arsenic* be an original production, whose particles, before thus exhibited, were not *arsenic*, but first became such in the exhibition; or rather, whether its origination consists only in a separation from another body, wherein indeed

indeed it cannot have lain as a snow-white powder, yet as a formal *arsenic* in an ore form; as neither sulphur is made from *pyrites*, nor quicksilver from cinnabar, but both of them separated from these bodies, is a question that has some difficulty? The first is not impossible, simple bodies first usually separating from mixts or compounds; yet the second is the more probable, as the black *arsenic*-ore, consequently, what is prepared to hand, is not combined with any coarse, fixed earth, to unfit it for such a degree of fining and whiteness; not to mention the genuine smalt-cobald, which often, in certain circumstances, is seen dissolveable both in the upper and lower *weatherings*, a circumstance never observed in a *misspickel* or *arsenic-pyrites*, however long exposed, as I myself have remarked, in all manner of air.

What makes this spontaneous purification of the *arsenic* a difficult matter to be credited, is the prejudice entertained, that the action of the fire is absolutely necessary for that purpose; though nothing is more evident than the spontaneous resolution and vitriolisation of the *pyrites*: and at Wenseen, in the territory of Lauenstein, in the Electorate of Hanover, a beautiful, transparent, yellow sulphur *breaks*, besides in several parts in Hungary, without the action of any observable fire; and the mercurification of metals, or rather their ores, is no other way to be fundamentally laid, than by gentle macerations, with appropriated salts and saline waters, and by the action of the insipid, powerful body of the air.

(2.) *Arsenic* is also often found in the earth perfectly native, without any other admixture, yet in a different form; I mean a semi-metallic fly-stone

O 4 form.

form. This ore generally looks externally of a dark-grey, and sometimes quite black; yet, upon breaking, it appears of a bright, metallic, leady colour; but upon lying exposed for a while in the air, is again overcast with the same blackness as before. Externally it seems like *testaceous cobald*, as if made up of shells laid one over the other; yet, internally, these run all into one another, without further distinction of layers. Some also call it *cobald* and *testaceous cobald*, especially miners, who call every thing cobald, that is either poisonous, or with which they are unacquainted; though the more cautious and distinct appellation would be, *black poison-ore*, *fossile fly-stone*, or even *fossile black arsenic*: for, in its genuine *mixtion*, without any other mineral adhering to, or interspersed with it, it is not only entirely fugitive, not leaving the least fixed earth behind, but in the fire it exhibits altogether the same appearance as the factitious fly-stone from *mispickel*.

It was formerly dug for at a certain Misnian *arsenic*-work near Schwartzenberg, and the Joachimsthal, in Bohemia, is remarkable for it; and it is said to be no stranger at Johan-Georgen-Stadt and Ehrenfridersdorff in Misnia, where the beautiful, transparent, *red goldish* ore breaks. The circumstance, namely, that such *red goldish* ore affects, or is affected by this poison-ore, must yield no despicable hints to diligent enquirers into nature; though I would be far from affirming the *red goldish* ore to be produced from it: but here let the proper caution be made use of which a careful one should ever keep in his eye, when, for avoiding fallacious conclusions, he would judge of the origination of two sorts of ores, lying near, or entangled in each other.

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As one or other circumstance might easily mislead us to a false conclusion ; for instance, that this *red-goldish* ore is highly, nay, I had almost said, allowing for its silver contents, entirely *arsenical*, and not sulphureous : further, that another silver-ore, as the *glassy*, which has only sulphur, and no *arsenic* for its mineralising cause, is, however, not to be found there ; (unless it should happen to be conveyed thither, as things the most foreign may, from other veins) whereas otherwise it is not uncommon for *red-goldish* and *glassy* ores, readily to lie near, and to be entangled in each other : moreover, that otherwise no sulphur-ore is found there ; omitting other circumstances which might be mentioned ; as, that the *red-goldish* lodge in this poison-ore as so many kernells in their shells. This, however, I must here say for *arsenic* (not out of any alchemical views, but only in regard to its universal treatment in ore-smeltings, and the like, and from some experience I have had of it) that it wants not a great deal to become a silver.

(3.) *Arsenic* may be supposed both to lodge in, and to be actually educed from fossile sandarach ; as it is certain, sandarach consists of that and some sulphur. This mineral is also found in the fossile orpiment, partly kidney wise, partly as so many fibres, also separately in fissures in the barren rock, as I have had it out of the sulphur-grooves, both from Cretnitz in Hungary, and from Turkey, likewise from Frantz-Coronzay, near Tobaga, by Neusohl, in Hungary ; affording the same hints to the enquirer, with respect to its origination, as were above given for the fossile white *arsenic*. Now both sorts, 'tis true, especially the second, are things very rare and uncommon in mineral collections ; and I dare affirm, a person intelligent in the nature

nature and encheiresis of *arsenic*, may in this same native sandarach, hit upon something to his purpose. The means of separating the *arsenic* from its adhering sulphur, and thus exhibiting it pure, is to add something, to which the sulphur more readily fastens; whereby it will let go the *arsenic*. This is the foundation of all separations, and what gives a hint for finding out other means to the same end, that would otherwise remain unknown.

(4.) *Arsenic* is found almost in all, or at least most ores; sometimes only incidentally, sometimes essentially: in such manner, that besides its little or no other fugitive substance, capable of reducing metals to their ore-state, which sulphur and arsenic alone effect, can be shewn from ores; incidentally it lodges in almost all *sulphur-pyrites*, as may certainly be concluded from the desulphuration of the purest sort; from the never-failing grey colour of crude sulphur; and from the sandarach, tho' small in quantity, procured from fining such crude sulphur; though some sorts of *pyrites*, particularly the round, yet that not always, stand excepted. The *copper-pyrites* and copper-ores contain somewhat more of it, and the richer in it, the richer they prove in copper, and the poorer, the less copper they afford: and by my experiments, none is procurable from them when they are purely martial; and in a sort of copper-ores, looking almost like a white *pyrites*, in the volatile part the *arsenic* is the principal; whence also the white colour arises; whereas otherwise in *copper-pyrites* and ores, the sulphur generally predominates.

In the *lead-glitter*, the lead has left but very little room for it, being almost all of it, enveloped in pure sulphur. On the contrary, *arsenic* lodges essentially

sentially in the *red-goldish* ore, as appears by the smell in roasting, by the poison-meal procured in sublimation, also from its relation to iron: seeing it does not part from, but rather runs together with it into a cake, without letting fall the silver, like as a *sulphurated* silver does; for instance, the glassy ore, after the manner of an antimony. And here it is worth remarking, that the *red-goldish* ore usually manifests itself in the fire no other than as a spad, by its starting and springing.

Arsenic lodges in *white-goldish* ore, *fallow* ore, *fallow-copper* and white ores: the first, on the score of its silver-yield, belongs to the class of silver ores; the others, on account of their copper-yield, to that of copper-ores.

Arsenic in the *cobalds*, from which the smalt is prepared, and in the *kupffer-nickels*, which are allied to cobalds, is all in all, as not to exhibit the least sulphur, as such. The finer tin-ores, called *zinn-graupen* (not the coarser, called *zwitter*, such a mixed mass being never without *arsenic-pyrites*, *wolfram*, &c. and yielding with us the greatest quantity of *arsenic-meal* for the *arsenic-huts*) beside their metal, consist of nothing else.

There are also *arsenical* lutes, clays, or marl-earths; as here in the *Herrn-grund* at the *Besibert-glück*. In stone I have not hitherto discovered any, but, I cannot say, I ever examined them with that view; tho' I have often for sulphur. In water we may rather expect to find sulphur than arsenic; yet there are instances of arsenic's insinuating into mineral waters; and it may, by art, be incorporated with water, in conjunction with sulphur and vitriol,

triol, without which it cannot ; as I have shewn from the *Friburg-schlacken-bade* *.

(5.) Arsenic lodges in *pyrites*, and essentially in the white sort. This *pyrites*, and the smalt-cobald, are here at *Friburg* the principal sorts ; the former is a whitish sort, consisting of iron, a crude earth and arsenic ; not so readily found as the other sorts, and never under the under-turf earth, nor readily in squats, but commonly in veins. At *Friberg* in particular, it *breaks* near coarse veins, as mock-lead, sulphur, copper-*pyrites* and *glitter* ; particularly, it every where accompanies mock-lead : in the *Obergeburg* it readily lies near *Zwitter* : besides iron, it contains but a very inconsiderable share of silver ; it is picked out from among our ores, as being not only unserviceable in our smeltings, but also rapacious, or detrimental to the procuring the full yield of metal ; its arsenic, if not well discharged at first, manifesting its ill effects not only in the lead and copper works, but also in the business of cupellation, besides proving prejudicial to the litharge. It is usually employed for making arsenic, tho' only incidentally with us, on the score of the charges. The arsenic rises out of it, and cobald, like a white-grey fume, settling like a white-grey powder in the receptacles prepared for it, as in so many aludels. The proportion of arsenic in such *pyrites* is generally a third, and rather over than under : and thus, it exceeds the proportion of sulphur in the *sulphur-pyrites*, which at most amounts but to a fourth of the other constituent parts : and these proportions are the more to be remarked, as they do not offer only in a few instances, but are observed to hold constantly.

* Breslaw Collection, P. 9.

We shall now consider the properties of *arsenic*, or rather its ore; (1.) In the earth. (2.) Air. (3.) Fire.

(1.) Its bed in the earth we have already considered; only this circumstance is to be added, in which it differs from the *sulphur-pyrites*; viz. that it always *breaks* near other ores; and only in fissures and veins, never in *nests*, as the *sulphur-pyrites*. The *white-pyrites* does not dissolve, crumble, vitriolise, or in the language of miners, become *weathered*, as the yellowish and yellow do, especially the first; for (1.) it contains no acid salt, as sulphur does, capable of exerting itself, and fastening on the iron-earth to the destruction of the whole texture. (2.) *Arsenic* and iron, of which the white *pyrites* consists, are too closely entangled, much more so than sulphur and iron. Whence might be sooner surmised the *weathering* or dissolution of the fossil black *arsenic*, or *fly-stone*, as being combined neither with iron nor any thing else. Lastly, the *arsenic* in the above-mentioned clays, also the pure, white *groove-arsenic* of *Joachimsthal*; being the former (from the mentioned clays being at the same time vitriolic) a *sulphur-pyrites*; the vitriol, arising from the destruction of the ore, carries along with it, by means of the water, that small *arsenical* portion mixed in therewith; the latter has for its ground the adjoining black grey *poisen-ore*, not our *arsenic pyrites*, as not being found near it.

(2.) In the air, the *white pyrite* maintains itself no less constant and unchangeable in its *mixtion*, in what manner, for what time, or in what place ever it be exposed. Nay, it needs must, as it is evident, *arsenic* is the grand, if not the only cause, why the *sulphur*

sulphur-pyrites, that are but a little *arsenical*, require more time and labour, nay even shew almost an impossibility of dissolution. It is somewhat peculiar to the small-cobalds, that they strike out a kind of peach-blooms ; and also under certain encheir-fes, yield a peculiar vitriol ; nay the pure sort do the same, even such as manifest neither the least sulphur, nor *sulphur-pyrites* ; though it may be queried, whether the bismuth-ore, which often quite unobserved, lies interspersed amongst it, be, if not the principal and sole cause, as seems probable, at least a concurring cause : or, whether the cobald itself, which may here be alledged instead of the genuine *arsenic-pyrites*, be itself capable of such a change.

(3.) The relation of the *white-pyrites* to the fire may be considered, partly in regard to the fire itself, partly to the other bodies. As to the first, most of the remarks, that give any light to the knowledge of this ore, have been mentioned above : but some things still want to be cleared up ; which may be best done by comparing it with the *sulphur-pyrites*, and reducing what we have to say on this head to a few short propositions.

(1.) The *white-pyrites* parts with its *arsenic*, of itself, without any *additions*, in which it agrees with the *sulphur-pyrites*, tho' not with the same promptness, but rather reluctantly, and not without a considerable degree of fire. The reason is, because *arsenic* sticks closer to its earth than sulphur does to its earth, which in the former is somewhat more crude, in both, irony ; insomuch, that in somewhat too brisk a fire, it is apt to cake or run, rather than to separate, whereas the same does not happen, scarce even by means of art, with respect to the *sulphur-pyrites*. This the *arsenic* very plainly shews, when combined

bined with sulphur ; and in copper-ore, with a copper-iron earth : and this gives a hint to roast with the greatest caution, not with a strong, brisk fire, both the copper-ores for copper-proofs, as these never want arsenic, and the cobaldish silver-ores, for silver : also to burn well and with the greatest attention the copper-stone ; as in the one a caking, or an impure silver-grain, may be expected ; in the other, a great deal of *arsenical* impurity in the black-copper, with a large share of copper *speise* or *leg*. Why *arsenic* adheres more obstinately than sulphur, is, doubtless, owing to its being a metal, at least a semi-metal ; whereby, in its entire nature, texture, and weight, it must approach nearer to an actual metal-earth, either iron or copper, than the tender, light, saline, and inflammable body of sulphur. Nay, all *arsenical* ores let go their fugitive, poisonous portion ; for instance, cobald, whether or no it yields smalt, also *kupffer-nickel*, *red-goldish* ore and *zwitter*. Yet here we must not omit observing, as something very remarkable, that the *sulphur-pyrites*, when not at all, or but little *arsenical*, yields its sulphur very readily, and without leaving any residue ; though the sulphur, which is along with the lead in the *glitter* or galena, takes a longer time for separation ; sticks closer still to the regulus, as is but too well known from its incineration for making the glass, and rather carries off quicksilver along with itself than lets it go.

It may be asked, whether it be not possible so to unite a metal with arsenic, as to sublime it therewith, in the same manner as we do sulphur and quicksilver.

And here (1.) the question is not concerning a small quantity of metal, as all *arsenics* may thus affect all sorts of metals ; for instance, the lead and the

the silver in the lead-working, the copper in the black-copper-working.

(2.) Sulphur and *arsenic* have no other affinity than that they are the two grand causes of mineralisation, or of reducing metals to their ore-state, and that only in regard to iron and copper: but if any thing must be put on a footing with *arsenic*, it must needs be quicksilver rather than sulphur. *Arsenic* is a semi-metal, quicksilver not much other. So that the question is reduced to this point, whether the *arsenic* will not also, like quicksilver, bear the being combined and carried over along with the sulphur: and for this the sandarach affords a plain answer, and an ocular demonstration; as in this case, the carrying over of the *arsenic* by the sulphur, happens as in the manner of quicksilver, that the third body, namely the sandarach, educed from these two, may be considered as a *philosophical cinnabar*.

Moreover, *Arsenic* holds firmer still in its *pyrites*, when either by accident, or with design, it happens to cake or run together with its accompanying iron-earth; which shews it would stand the fire, and that it wants something in iron for that purpose. The relation of iron to other metals has been shewn above, chap. iv. by the magnet.

(3.) 'Tis no wonder, that *arsenic*, in its separated state, can so very difficultly be again introduced into smelted iron; even as difficultly as it is to exhibit a *sulphur pyrites* by art; seeing it depends on a due appropriation of the iron, and the properly exhibiting its earth-form. On which encheireses and circumstances, many, and those the most important combinations, especially in the imitations

tations of nature, entirely depend. With *sulphur-pyrites* it in some measure succeeds; as the *slag*, which sometimes settles on the lead, deposited out of lead-ore by means of iron, and which certainly consists of iron and sulphur, is to be regarded as a kind of *pyrites*.

(4.) The *arsenic* in the *white-pyrites* is not sufficiently saturated with iron-earth, but can still bear with facility almost as much again, as it had already received; as may be shewn by its *regulation*, which is performed with iron. We have pure, clean sulphur, also pure clean *arsenic* in the bowels of the earth; and thus they may not only consist, but be also produced without iron.

(5.) The *white-pyrites* contains also a little silver; in this entirely agreeing with the *sulphur pyrites*. But when *arsenic* is combined with an earth, yielding smalt, and then called *cobald*, it becomes remarkably more silvery, yet in variable degrees: this we also observe of *sulphur-pyrites*, when its iron-earth is coppery. And the comparing together of the *white* and *yellow pyrites* in general, with respect to their earths; at one time yielding smalt, at another copper, and the exaltation of their silver-yield hence visibly depending, would be worth our peculiar attention. And he who would verify his suspicions about noble *miss-pickels*, should accurately examine the sample he is about to employ for proof, in order not to be deceived by other unobserved, interspersed veins therein.

(6.) The *pyrites gold* is not very common. As I would not be imposed upon by the *white*, as little would I by the *yellow* colour of the *sulphur-pyrites*. I am well aware of the difference between white and

yellow metals, a difference no way groundless ; but there are middle metals, and these stand ranged with the intermediate quicksilver, and arsenic certainly should not have been excluded.

(7) The fugitive portion of the white *pyrites* is almost as well affected and inclined to iron as to bismuth, tin, and zink ; whereas regulus of antimony, and lead, are ill affected and unfriendly thereto ; seeing the latter can at no rate bear it nor run together with it, even when *dead*, or reduced to a glas. The former, indeed, unites with it at length, but destroys it : for the magnet, as above mentioned, touches not the iron, that is smelted with regulus ; whereas it has the least aversion possible to *arsenic*, tin, zink, and bismuth, even should the iron happen to be strongly dosed with them.

(8.) White *pyrites* holds no sulphur, nor any sandarach.

(9.) It smells in the fire like garlick ; its smell is biting-sharp or pungent.

(10.) It diffuses its smell in the air to a greater distance than sulphur does,

(11.) In the strongest degree of fire it leaves a black glass behind, as we experience of any other iron mineral.

(12.) *Arsenic* makes copper white, but at the same time brittle.

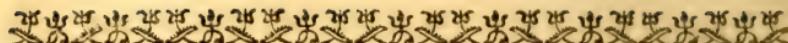
(13.) It leaves iron its colour, and makes it eager also.

(14.) The

(14.) The glass, to which it runs along with lead, is something extraordinary: not to mention other remarks at present.

Once more; *arsenic*, *zink*, and *phosphorus*, stand greatly allied to, and probably are derived from each other. *Zink* and *phosphorus* are bodies susceptible both of fire and flame; the former, only by an external accension; the latter, by an internal self motion, by means of the air. *Zink* smells fetid, like *phosphorus*, and *phosphorus* smells like hut-fume. *Phosphorus* unites with quicksilver. *Arsenic* and quicksilver are nearly allied. In *cadmia-fornacum* there is an actual, tho' not a formal *zink*. *Arsenic* certainly lodges in, and *zink* is only derived from ore: yet they are produced one after the other; first, the *arsenic*, then the *zink*; they also adhere to each other. *Phosphorus* too may be prepared from *arsenic*, or an *arsenical* body.

Reader, weigh well what I have already mentioned on this head; and here, for thy further information, take an extraordinary experiment of the celebrated Dr. Meuder's *Dresden*, lately discovered by him, and imparted to me: Take orpiment and iron-filings, equal parts, and subliming the mixt mass in a body or cucurbit, among the sublimate, thus procured, rub in on a porphyry, ten or twelve parts of lunar crystals; then shooting out the whole on paper, it will instantly take fire.



C H A P. XI.

Of the SILVER in the PYRITES.

AS to the *silver* in the *pyrites*, it is an undoubted truth, allowed by every careful assayer, and which I myself have experienced, that *pyrites*, as such, never holds above half a drachm of silver in the centner. For, tho' sometimes the proofs should rise to 1, 2, 3, 4, 5, and 6 drachms, as I have often observed such various *yields*, we are at the same time to know (1.) That such sort of *pyrites* is commonly coppery; and that the copper therein is, if not the cause, yet the sign of the admixture of other ore. (2.) That such yieldy *pyrites-mixt-work*, or *pyrites-meal*, has often other veins unobservedly interspersed amongst it, which may greatly raise and heighten the *yield*; and to this sort may be sometimes referred the cubical, marcasitical *pyrites*, such as those of Pretzschendorff, which appear pure and unmixed, tho' internally they make an appearance of being *glittery* and *mock-leady*. (3.) That hence the proofs vary much, nay sometimes so far as to fall short of half a drachm.

The same thing holds of the *white pyrites*, namely, the *mispickel*, or *poison-pyrites*, an half, or a quarter of an ounce may often be procured from them; but a drachm, half a drachm, and next to nothing at all, are generally what the *proof-schedule* shows. Yet here, for particular reasons, I must allow some silver to the *white* rather than to the *yellowish*, or *sulphur pyrites*: and I have been informed from Sweden, that they have there a *mispickel* of

of four ounces in *silver-yield*; though it may be queried, whether such be a pure *misspickel*, and not rather a smalt-cobald, these being often not easily distinguishable, and generally *silvery*. But here again I find, even a *misspickel*, that *breaks* in amongst the noblest veins, tho' rarely, to be no more *silvery* than another from coarse veins.

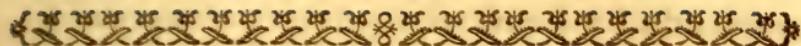
But when the *pyrites* is coppery, as from the copper-yield we may suspect the coction of some other ore and metal, we may then rather hope for *silver*, tho' not constantly, not indeed as an essential, but as an incidental part of the *pyrites*, in the same manner as copper itlself is so. Nay, this incidentality of the *silver* in *copper-pyrites* is still so uncertain, that there is no measuring or proportioning the yield of the *silver*, as might be imagined, by that of the copper. But there are *copper-pyrites*, very rich in copper, which nevertheless do not yield the more *silver*, nay sometimes yield less than those that are poorer in copper. And here we must be upon our guard against being imposed upon by names given to *pyrites*, either from the colour, the *silver-vein*, where they *break*, or their use in smelting for *silver*.

Thus, from Norway, I have had, under the title of a *silver-pyrites*, a barren stone or rock, consisting of small, tender layers of *quartz* and *glimmer* interchangeably, with foils or spangles of *silver* upon it, where it had been broke off. Now, not to mention, that we are not careful enough to distinguish *pyrites* from flint or *quartz*, which this stone really was, I shall here only observe, how far-fetched such denominations often are, which point not at the essence, but accidents of things; as such pretended *silver-pyrites* hold no *silver* of themselves,

but happen to be furnished with only such as is adventitious and foreign. The same judgment we ought to pass on the Latin appellations, *pyrites argenteus*, or *argentarius*, as taken either from the colour, and denoting the same as *pyrites argentei coloris*, and thus only a *white pyrites*, of which in the preceding chapter : or, from its holding silver only without any other metal, as * *Rulandus* affirms ; whence it should rather have some other name than that of *pyrites*. After all, so little *silver* is to be expected from *pyrites*, that were not the *sulphur-pyrites* serviceable for making the *crude-stone*, or for *sulphur* and *vitriol* ; and the *copper-pyrites* serviceable for copper, it would not be worth while to dig for and smelt them.

* Lex. page 390.





C H A P. XII.

Of the G O L D in the P Y R I T E S.

IF silver hath no great share in the *pyrites*, gold has still much less: I, for my part, find little or none therein, though nothing be more common in the mouths of men than the names, *gold-pyrites*, *gold-marcasite*. It is, I own, no small pain to me, to be obliged to contradict what so many ingenious and learned persons before me have asserted to this purpose; however, I cannot help exposing such pretences, seeing even what actual *gold*, after the greatest care and attention, we may happen to procure from *pyrites*, proves very inconsiderable, and next to nothing; and then it may be queried, whether it was actually in it, or produced by means of the process and *additions*. 'Tis absurd to pretend, in support of the common opinion, the volatility of this *gold*, as it may be asked, what the appearance, and what the signs are, by which it may be distinguished? We have, 'tis true, volatile metals, in particular, the common and philosophical leads; nay, all metals may be volatilised.

But it will be alledged, there is no catching this volatile *gold*, in *an open fire*; but may not subliming vessels be employed, by means of which, a little of what the violence of the fire forces off may be recovered in order to trial? But, to save my reader a good deal

deal of trouble, I can assure him, that after having examined all the sorts of hut-fumes, from the several operations of *crude-working*, working for lead and copper, and those from the fining-hearths, with a view to this volatile *gold*; I found, indeed, a small share of ignoble metals, in particular, lead and copper, also a little silver in the lead, but never the least sign either of a volatile or fixed *gold*; as those employed at the roasting-hearths and smelting-furnaces, for collecting the dissipated silver, and who having assayed the silver procured from the fume, for *gold*, will readily own. Tho' had this surmise any foundation, the *gold* could not fail shewing itself in such hut-fumes, where *pyrites* of all kinds, and in all quantities, are worked, in a degree of fire, where all metals must become fugitive. That in Hungary and Transilvania some *gold* should be procured from the fume-works, we are not to wonder, as their ores contain a fixed *gold*, which, like the silver with us, may be carried off in the arsenical fume in very minute particles; but, by the method of depart, or by the assay-furnace, no violence of fire can be charged with volatilising the *gold*; and yet in neither of these ways do we discover any in the *pyrites*.

Should it be further alledged, that it is only an immature, or embrionated *gold*, this is no more than a mere subterfuge; 'tis as easily said, that cobald, tin, and the like, are an immature silver, as is, indeed, often said, but never proved; tho' it must be allowed, tin, and the like, greatly resemble silver. *Pyrites* also boasts of its beautiful gold-yellow, which has served to deceive many, without their being able to procure any one sort of *gold* from it.

I would

I would not here be understood as depreciating the following propositions, *viz.* (1.) That a perfect, or, if you rather choose it, a ripe metal, may be made from an imperfect metal. (2.) That some *pyritæ* are not entirely without some small share of *gold*. The first the experience of every one may affirm, in the least conversant in the business of minerals and metals, with any care and attention; though the thing cannot be reduced to any certain theory or rule, to be depended on at all times. But in all these proofs, where, for instance, copper and iron particles are transmuted or converted to *gold*, as also some particles of lead, tin, regulus, &c. to silver, it by no means follows, that iron and copper are an immature *gold*; or lead, tin, and regulus, an immature silver.

For, though I might call such a conversion a maturation, and though there were instances thereof, yet it still remains a question, whether other, nay, all educctions of the nobler metals, where a formal tincture is not employed (and such processes may, in some measure, be called *particular*) are only *productions*, arising, as a third thing, from the running and mixing together of two or three sorts of particles, and not, in effect and propriety, *educctions*, not always to be denominated maturations, or transmutations.

It is one thing to transmute a salt, for instance, to volatilise common salt *per se*, which is certainly practicable; another, to educe a salt by the addition of a second and third matter, as an *oleum vitrioli dulce*, by means of quicklime, or a lixivious salt, as is a well known case.

Metals,

Metals, undoubtedly, are near allied to each other; though why supposed so only in the ascending, and not the collateral line? and philosophers borrowing the term *maturatio*n from the vegetable kingdom, it is only in the way of comparison, and serves merely as a demonstration, but does not amount to an illustration: either it is out of a certain deference to the *great work*, they forbear the use of the term *transmutation*; or, to avoid falling by the ears with the Aristotelians, who, from their doctrine of *genus* and *species*, disclaim all transmutation of metals.

Before I enter upon assigning the quantity of *gold* procurable from the *pyrites*, I must premise my method of taking and working the proofs. For the first, with the greatest care and attention possible, I pick out the pure steely or close sort; then, as the *gold* in the *pyrites*, if any, is only to be had by procuring its silver, in the *grain* of which the *gold* lodges, I have accordingly made the proofs for silver; and as, generally, the *silver-grain* proves to be very small (and neither the smallest nor the largest is to be assumed) namely, in the *sulphur-iron-pyrites* amounting to half a drachm, and in *copper-pyrites*, or copper-ore, to two drachms; with so very small a *grain* there is no making a certain proof for *gold* by the *depart*; I have therefore worked between six and eight centners at once, on as many different assay-pots and copels, and, at last, run the silver together into one *grain*, which afterwards committing to the *depart-water*, I, after edulcoration and ignition, weigh the black calx. I hold this to be the best method, as it supersedes, if nothing happen to be procured by it, the several operations of cementation, maceration, ignition, and extinction, if you will suppose there is any *gold*; for, some

some of these, particularly cementation, may have some effect as to the encrease of the gold.

To educe the *gold* out of the *pyrites* by *aqua regis*, seems to be an uncertain method, as the *gold* is generally entangled, not only in much foreign admixture, but in such metals, as copper and iron, on which *aqua regis* equally works as on *gold*; yet this I have also done, and, after *incotion*, copelled the precipitated mass, but without any effect: nay, if by the former method I procured any thing, by the latter, on the contrary, I have rarely succeeded at all, or in a far less quantity.

In pure *sulphur-iron-pyrites* there is not the least *gold*, a thing well to be observed, even should it happen to be the *minera martis solaris Hassiaca* itself, the sulphur of which, for its high purity, is greatly to be valued (but its vitriol must yield to a factitious, pure iron-vitriol, but much more to a vitriol from calamy, also to the green, fossile, Hungarian vitriol) but its *gold* is only imaginary: much the same holds of those *iron-pyrites* which are but very little coppery, as also of most *pyrites* in nature. Among these there is now and then a proof, where the *mark* of silver holds about one quarter, or one half, or one *heller* * of *gold*; but when the centner or quintal of ore gives forth one, one half, nay, only one quarter of a drachm of silver, and you come to calculate the number of centners of such ore, necessary for the eduction of a mark of silver, the *gold* to a centner must be very inconsiderable, nay, not to be calculated, much less be visible, or be manifested by the most tender, sensible scales; can it then be thought worth while to mention *gold* in this case?

But

* Seven hellers make a penny weight, thirty-two hellers a loth, or half ounce.

But it will be alledged, the *copper-pyrites*, and *rites-copper-ores*, as copper is nearer allied to *gold* than iron, yield some *gold*; yet with these, after all my labour and trouble, I succeeded no better. It may indeed happen, that some Hungarian sorts, which have served to set the world a-gog after *copper-pyrites*, shall give some evidence of their containing *gold*; but of these hereafter. One would not readily suppose *gold* to be in the white or arsenic *pyrites*, seeing it does not appear yellow, but of a silver white, which is the reason the beautiful yellow *pyrites* have been pitched upon, though that yellow cast be only owing to their sulphur, and afterwards heightened by the copper, nay, often superficial only; and as little from the colour must we imagine silver in the white *pyrites*; though it contains such powers, that, under a due dosing with other matters, may contribute something towards the eduction of both silver and *gold*.

From the several proofs I have made of a variety of *pyrites* from different parts of Germany and Hungary, I have found, that the sort yielding *gold* have had either tender and unobserved eyes of richer ores, especially rich silver-ore, or spangles of native gold, or some *quartz* (in which gold generally lodges, and not in *pyrites*) entangled and mixed with the sample under examination; and therefore, before ever the sample be beat quite fine, and committed to the furnace, it is highly necessary carefully to inspect it both by the naked and armed eye, and to omit making no experiment that may contribute to discover it, as *gold* may lie concealed in the tenderest spangles and dust: as (1.) ignition, whereby the *gold* is not only heightened in colour, especially when it happens to be smutted, or,

or, by means of a mercurial admixture, over-pale, but to break and crumble the sample which is commonly *quartz*, and thereby to expose to view more sides of veins, where the *gold* commonly lodges; and the *pyrites*, for which the *gold*, being so crude, cannot always be distinguished, becoming dark, the *gold* must needs shew to the greater advantage: (2.) amalgamation, on which the most skilful hands should be employed, as the *gold*, being in such tender spangles, is apt to float on the water: (3.) *aqua regis*, which is still better, taking the ore crude and unroasted: lastly, the repeating the proof; when the difference of yield must at least shew the *gold* either accompanying, or lodged in the *pyrites*.

The following remarks may here be justly made; (1.) that as no great stress is to be laid on the cubical or marcasitical, as little is there on the round figure of the *pyrites*, for their *gold*-yield: (2.) that the pale-white colour of *pyrites* should be no prejudice against our examining them for *gold*; nor its yellow colour, either that essential to its *mixtion* (such as the *copper-pyrites*) or superficial only, from an external *weathering*, be any prejudice against their *gold*: (3.) among all the sorts of *pyrites*, I have never met with any containing *gold* alone (namely, in an *ory*, *pyritous* state) without silver, a circumstance worth our greatest attention; and it may be doubted, whether there is an instance of a single *gold*-ore in nature: (4.) that there is no *pyrites* whose silver does not considerably exceed its *gold*-yield: lastly, that the *gold*-yield, of any consequence in *pyrites*, generally amounts to a penny weight in the centner, or a little over or under; which constant proportion makes it highly probable, the *gold*-yield is procured from the *pyrites* as such, and not

not from native *gold*, or other accompanying veins, seeing the proportion would, in that case, prove various and inconstant; and then the question will be, whether the *gold* be produced from it?

Now when there is *gold* in *pyrites*, and I would procure it, the body of the *pyrites* must necessarily be destroyed, ceasing to be what it was, and in part commencing a different thing, a new production, mixtion, and composition; as we have a convincing instance to this purpose in vitriol, a matter not lodged in, but produced from *pyrites*.

In the first place, I speak of such destructions as happen *per se*, without the addition of other matters; for instance, common and corrosive waters, salts, oil, sulphur, &c. poured, rubbed, or mixed in variously, though not without all material influx of the air and fire: (2.) of such destructions as are commonly called *processes*, wherein, along with *pyrites*, are mixed-in saline, sulphureous, mercurial, and arsenical matters, also metals and semi-metals, which have usually some effect: (3.) I would ask, whether there may not be methods, where, from the running together fit particles, there may not, by means of action and re-action, impregnation, and conception, new substances, forms, and productions be procured; and thus something of *gold* be procured, that neither was in the subject, nor in the additions. Now, (1.) as to the destructions happening without any palpable additions, and the concurrence of any other matter, which might be held as barely instrumental, without the suspicion of any material influx on the mixtions, as the lead on the copel, not certainly to be regarded with the common eye of an assayer; the depart water, which, in its habitude

bitude and fitness to its subject body, shews something more than a bare instrumentality ; or, at least the *aqua regis*, and the precipitant employed for discharging out of it again the earth swallowed up by it : I say, not reckoning these, the destructions of mineral bodies in general, and of ores in particular, not only cause separations, but transformations also ; not only exhibiting to view what they contain, but also some new *mixt*, a third body ; and that for this reason, namely, that they are generally *decompounds* and *superdecompounds* : and not only *compounds*, but mixts, nay, simple particles themselves, which, when brought, either by the fire or air, into a state of motion, activity, and conception, operate upon each other.

By means of destruction, the parts of the whole separate in one part, and again unite in another, or let go some of their *mixtion*, that others may combine the closer ; and these new combinations happen in the very act and instant of the separations themselves ; as in the case of vitriol, which is not actually contained in, but generated from *pyrites* ; as is evident, that in the production of it, the entire body of the sulphur is excluded from communicating but a part, namely, its acid salt ; so that its own proper subsistence, as a sulphur, must needs be destroyed. The parts forming the new production are often already in the subject, and only a new cohesion or texture procured ; frequently they are fetched from some other quarter, either apart, or together, and often arise from the destruction and mutual action of the parts, once set loose and rubbing against each other. The vitriol-acid, and the metallic-earth, are both contained in the *pyrites*, and that in a large proportion, only not in a vitriolic mixtion ; but the former

mer in the sulphur, the latter not only entangled in the sulphur, but also in another crude earth. In *alum-shiver* there is no vitriol-acid at all, but it is fetched either from the air, or generated at once by fire and air, or by fire alone; tho' fire, without air, can neither act instrumentally nor materially; neither is the white earth of alum procurable from the ore, nor therefore to be considered as a genuine production.

The water, which is in a large quantity, both in vitriol and alum, is neither in the *pyrites* nor alum-ore, considered in their *mixtion*, but is imparted to it either from the air, or by men's hands. The same also holds of other vitriols, produced from their own ore alone; though I cannot here recollect any but the white, and the sort from bismuth-ore and cobald, or from bismuth itself, as I have experienced. The former contains a white, though coppery earth, which is neither from the ore, nor from the accompanying shivery, loamy, and *kneify* minerals; the latter, or the bismuth-cobaldish, a green, though derivable from the ground-earth of the small-cobald-ore, as green and blue are in nature near allied; but the peach-bloom colour, nay, the purple-red, as their beautiful appearance deserves a peculiar regard, must needs have their foundation in a peculiar conformation of their earths.

Thus in these productions, formed as much as may be *per se*, foreign matters, as air and fire, have an influx; often the air alone, as in the spontaneous vitriolisation of *pyrites*; often the fire alone, as in the vitriolisation of calamy; often both together, as again in the vitriolisation of the *pyrites*, which must first pass through the fire, and afterwards be exposed

exposed to the air, but properly both together, unless you would have a coaly or externally inflammable sort. Air and fire are here to be considered not only in their *instrumental*, but also in their *material* capacity; or if they must be called *instruments*, *immanent* rather than *transient*.

The air chiefly manifests its virtue on, and ingress into the bodies of plants and animals, as in good part not only being derived from it, and remaining under its influence, but as being of a softer texture; nor can minerals, least of all the sulphureous and bituminous, resist its action: nay, these are chiefly the bodies on which it performs destructions, separations, and new combinations, as sufficiently appears from vitriol and alum. In the *depths* of the earth it operates on minerals more powerfully than at the *day*, as being not only more actuated with a greater number of saline particles, but not so subject to be dissipated by the action of the wind and sun, consequently it has time and leisure to eat into veins and rock; nay, to destroy such bodies as, exposed to the open air, remain untouched, or become still harder, and more durable. It not only penetrates, but at the same time adheres to what it penetrates, with its fatty, saline, earthy and watry particles, which last are the vehicle wherein the others lodge, and are introduced and incorporated into the subject. The fatty and saline nature of the air cannot be disallowed by any one, considering its meteors, in particular, thunder and lightning, the habitude of pot-ash thereto, the corrosibility of iron and copper therein, &c. Only 'tis here to be hinted, that we do not extend too far the action of the acid of the air to the vitriolisation of *pyrites*, as being what is already plentifully present in the sulphur of the *pyrites*;

rites ; a desulphurated *pyrites*, and an exhausted *caput mortuum*, never yielding any vitriol.

Fire, which consists in the quickest degree of motion and incalescence of inflammable, fatty particles, imparts to the mixtion, partly from its own matter, partly from the flame of coals, wood, &c. applied externally, or from both together, something essential and material, that either before was not at all, or not in such mixtion and form therein ; as appears from an incinerated regulus of antimony, which proves heavier than it was before such incineration ; and from all the transformations of bodies containing any thing inflammable, which by the external fire is ever made the object of its own rage.

In all these dissolutions, new forms, or new productions, frequently occur, where separations are seldom seen ; yet where destructions happen *per se*, and are purely the effects of air and fire, without any thing besides, there we may rather expect separations, and that in mineral bodies : and if we would proceed accurately, the separations are to be verified by compositions. I speak of mineral bodies, and those both *compounds* and *decompounds* ; for, animal and vegetable bodies easily and certainly enough separate into their original earth and water, out of which they grew : and *mixts*, nay, often *compounds*, are of a nature, that the former bear not separation at all, the latter, not without some difficulty. In separations the parts of the body are already *formally* in it, what is otherwise produced, *potentially* only. Of the fire it is commonly said, that it is unfit for separations, as framing new mixtions only ; that the fire is a *destroyer*, not an *analyser* ; that the air, on the contrary, is a better separator

parator and dissolver; but in *decompounds*, such as minerals mostly are, the reverse may rather be affirmed; for, the fire rightly enough dissolves the *pyrites* into its parts, so as separately to exhibit its sulphur, arsenic, copper, and iron; whereas the air, by the act of vitriolisation, quite destroys the sulphur, not to mention the metallic portion, which in this case is taken into the vitriol-mafs, and thus becomes transformed.

Now to apply this to our *pyrites*; it may justly be asked, whether the *gold* be parted, or formed from it, and thus be either *formally*, or *potentially* therein? By spontaneous vitriolisation a *gold-yield* is neither to be induced, nor increased in the *pyrites*; nay, though by these destructions there happen extraordinary precipitations of some earthy particles, that often partake somewhat both of *gold* and *silver*; yet such conjectures are with difficulty proved: for, *gold-pyritæ* are either coppery, or arsenical, or participating generally of both. Now such do either not sufficiently, or not at all vitriolise; and fossile or native ochres, or *pyrites-earths*, several times assayed for *gold*, I found to have little or no yield.

Suppose now we have recourse to the fire, and then the *pyrites* either is, or is not roasted; in the latter case, it is taken crude, dosed with lead, and scorified, and the lead-regulus *driven*, or copelled, that is, the noble is driven or parted from the ignoble metal. Now here we procure a *silver-grain*, at least from the lead, were there no silver at all in the *pyrites* itself; in this grain the *gold* must lodge: this *silver-grain* is committed to depart-waters, namely, the *gold* parted from the silver, and ignited, which finishes the process. Now though

this method of working *pyrites* for gold should seem to be performed *per se*, without any foreign additions, yet that there only happens a bare separation, as no methods of coction, maceration, digestion, and maturation, have preceded, may prove a mere precarious assertion, without considering in the least the nature of lead in its volatility and activity, the efficacy of sulphur, and the mercurial seminal virtue of arsenic; especially when these powerful agents happen to be applied to, and to find proper tender matrices. All these are here effectually applied, whether the operation be carried on in the way of roasting, or of scorification with lead, the metallic earths exhibiting themselves as so many tenderly prepared matrices: and supposing the parts of the *pyrites* to do nothing towards the transformation and exaltation, yet the fire acts here no inconsiderable part, not only in the way of a separation, but also of an influx; whether by enriching the *phlogiston*, and metallising the matter, or by a higher virtue still, may be made a question.

Whilst I was engaged in these reflections, there came to my hands an extraordinary experiment of M. Homberg, from which he maintains, and with a good deal of probability, that in silver are contained particles of a gold-nature, which, in the course of the process, at first become perfect gold.
 ' Take between one and two *marks* of silver, which
 ' being assayed in the usual manner, with *aqua-*
fortis, in order to ascertain its containing no gold,
 ' melt it an hundred times over, and having con-
 ' tinued it each time in flux for an hour at least,
 ' depart it; you will procure a very sensible quan-
 ' tity of gold, which before was not to be found
 ' in the silver *.' 'Tis pity our author did not set
 down

* Mem. de l'Acad. &c. l'an. 1709. p. 141.

down the weight of the *gold* procured; also, that he does not inform us, whether the process was carried on with the same parcel of silver, and with the same *yield* over and over; though this cannot be, at least, seems not credible, as may appear from his second experiment, which shall be mentioned below, and as may be concluded from his judgement on it; and lastly, we have not Homberg's purse, for repeating such experiments. We may, however, firmly rely on his veracity, and conclude from this, how much reason we have, even in such mineral and metallic processes as happen *per se*, to expect new forms and productions.

For, in the experiment before us we have no ore, but a simple, and every way well parted metal; no *compound*, but a *mixt.* Here we have neither sulphur nor arsenic, as is in *pyrites*, nor lead, nor any thing else added: yet, how simple soever silver may appear, it is not really so; it ought to be observed, as appears from Homberg's second experiment, that the whole of the silver is not converted to *gold*, but only some particles, which have their certain number, weight, and measure, and are produced all, if not at the first, yet at the second and third trials. And what is it in silver, which thus is no *silver?* probably an earth.

A foreign metallic earth may be contained, to a considerable quantity, in silver, as may be judged from the universal mercurial affinity of metals, and particularly of iron-earth, which, notwithstanding, cannot escape *depart-waters*, and often proves to be that fallacious black calx, which we take for a *gold-calx*, though in fact it is no such thing: and if this earth, which turns to *gold*, be an iron-earth, may not the like, with more probability, be supposed in

pyrites-silver, as pyrites always contain iron; and gold be in quicksilver *potentially*, not *formally* and actually, but only in the proximate degree of becoming such. Hence appears, how much depends upon time and fire, and how, from the defect of one or the other, particularly of the highest degree of a glafs-house heat, we may after chance to miscarry in all our designs; and that what we may be apt to ascribe to extraordinary *additions* and *secrets*, may only be the effect of patience, time, and fire.

In the next place, Becher's experiment of making iron from loam and linseed oil offers itself to our notice; and this leads me to consider such ore and metal-smeltings, where the coal and flame happen to be in immediate contact with them, as is the case at all huts for smelting-ores; this also gives me an opportunity of clearing up a little more the question about the transformation of metals, and their mixtions; how they happen *per se*, or, at most, barely by the fatty wood-coals, and other, either vegetable or animal particles, coming to play in among them. For, though M. Lemery's reflections on this experiment staggered me greatly, in regard to Stahl's opinion about restoring the phlogiston, and its *material* influx on the metallic earths, nay, almost brought me over to be of his mind, yet I shall vouch for neither opinion, but leave them to stand or fall, at the judgement of the reader. M. Geoffroy, a member of the academy of sciences at Paris, did, in the year 1705, on occasion of Becher's experiment, start the following question, viz. *Whether it were possible to find plant-ashes having no iron?* or more distinctly, *Whether those iron-particles, actually procurable by the magnet from vegetable ashes, were really in the plants* in

in their fresh and unburnt state, or first produced therein by the act of incineration and burning? M. Lemery the younger, reasoning from the possibility of the thing, affirms the first; as from iron being contained in all upper garden-molds, whence plants must derive their nutritious juices: again, from iron, by means of water, changing to a salt or vitriol; to which might be added, that vegetable waters may affect what a formal acid vitriol salt cannot; as sufficiently appears from that macerating water, prepared for the use of iron-plates, from the fermented acetous juice of corn, of which we shall say something in the chapter on vitriol. After this, M. Lemery sets about examining the matter of fact, yet without alledging any one solid proof; only denying the allegations and conclusions of his antagonist, and, at last, answering his objections. M. Geoffroy undertakes to defend the last; and here he chiefly asks, how' tis possible for such a vitriolic vegetable juice not to affect the taste, as a single grain of vitriol may serve to impregnate several measures of water. Though the dispute seems to be but lamely managed on both sides, yet it must be allowed that the former has the advantage, at least in point of answering objections, tho' not that dexterity at defending his own position; and that, though I have always suspected the original of this iron in plants to be rather in their incineration, yet I cannot hitherto find proofs sufficient to satisfy myself, much less another, about it. And here the question is not, whether the iron-particles do, or do not actually lodge in the substance of the plant, the linseed oil, &c. but rather, whether the linseed oil, and the clay, or loam, do, by the operation, yield any iron, which before was neither in the one nor the other: for, M. Geoffroy readily allows, that both in the loam and oil, there is al-

ready some of this metal, previous to their addition, namely, *per se*, as appears by the magnet; tho' I doubt much, whether there be any in loam as such, a pure marl-earth. And M. Lemery cannot deny, but that by the addition more iron is procured than otherwise would from the matters taken apart: yet neither thus is the dispute at an end: for Geoffroy alleges that the marl, in order to its becoming iron, wants something, which by means of the linseed oil must be communicated to, and incorporared with it. Lemery, on the contrary, insists, that it wants nothing, only some impediment remains to be removed: the former, that there is no iron yet, but that it must be first produced: the latter, that it is already formally therein, and wants only to be separated from the foreign matters, that hinders its assuming a metallic form. The former, that what in the clay or loam stands in the way of the metallisation, as also of the magnet, is an acid, which may be removed by a fatty matter, as an absorbent or alcali; which appears not improbable, from the following circumstances; first, that acids usually reduce metals to an earthy, loamy form: again, that metals do by calcination rather encrease than decrease in weight, and thus lose nothing, that must again be refuned, but rather gain something.

But not to insist on the acid in loam and clay; a small matter therein cannot greatly contribute to fill up the pores of so much iron, as may be procured from it, there being more than a little acid requisite to reduce to earth only a small quantity of iron: or otherwise, I find not such a similitude of circumstances, as to believe, that an artificial metal-earth agrees only in this with a fossil. But it may be answered, which yet, I think, is not to be allowed him,

him, that when the formality of this experiment consisted only in removing an acid salt, and the vegetable fattiness acted here as an alcali ; this fattiness, as such, and in its unaltered state, cannot be said to effect it ; but may, when in the course of the operation it becomes reduced to an actual ash, and thus to an alkaline state. For, oil and fat, as such, remove no acid ; but consisting themselves mostly of such, increase its quantity rather ; but a lixivious salt effects it.

Still several difficulties offer that oppose a positive declaration from Lemery's opinion.

(1.) There will be requisite a much greater quantity of alcali to obtund a certain quantity of acid ; and in loam, by his own concession, there is much acid. Again, what quantity of alcali ashes does linseed oil afford ; nay, how much pure alcali is procured from the ashes ?

(2.) Why are not metallic earths reducible with pot-ash and the like ; and *lunæ cornua*, not again to silver, but much, nay almost all of it lost, when repeated by trials with alcali : whereas pitch, fat, rosin, and the like do, under proper treatment, reduce all the silver back to its metallic form : and yet, in the one case, such fatty matters scarce in their whole substance and weight amount to so much, as does the pot-ash employed in the other, tho' without any effect : and the least quantity of coal-dust reduces my *antimonium diaphoreticum*, as also my *vitrum antimonii* : whereas the former floats in the alcali, and under due cover and screen from coal-dust, for ever remains an earth, or goes sooner off in fume.

What-

Whatever probability there may be for Lemery's opinion in the encrease of weight of some metallic calces or earths, a thing not to be denied, yet till other convincing experiments can be produced, I hold the actual causality, or the formality of Becker's experiment to consist, not in removing matters, standing in the way of the metallisation ; nor in a way of unfolding all the iron-particles already extant, but in a material influx, and an addition of parts deficient ; in an essential communication of the metallising fattiness, and thus in a real formation. Consequently, that there is nothing in Lemery's opinion that can in the least invalidate my notion ; not only in regard to the metallisation of a *gold-earth* in *pyrites*, but also principally, in regard to the production of *gold*, extant therein neither in a metallic nor earthy form ; also in regard to the business of transformations, nay even transmutations.

To illustrate the destructions or dissolutions, performable by *additions*, and not by air and fire alone, I shall here alledge M. Homberg's experiment, promised above. ‘ Take and dissolve a *mark* of silver in aqua fortis, and remove what remains undissolved at the bottom of the glass : throw down this solution with common salt ; adulterate well the precipitate, and dry it. To this silver-calx take half as much regulus of antimony, well purified and reduced to a fine powder : mix all well together, and being put into a retort, drive it in a sand-heat, and there will come over about three ounces, or somewhat more, of a butter of antimony : raise your fire to the highest pitch, and you have the silver at the bottom of the retort, mixt with a part of the regulus of antimony. Put this silver into a crucible in an open smelting fire, wherein let it fume, till it can no longer, or till the regulus be entire-
ly

ly gone off. Melt this silver once more, nay twice, with a little borax and salt-petre, and it will prove as fine and ductile as a tested silver. Then granulate and dissolve it in aqua fortis, and you will have a number of small black flocks, which being melted, prove to genuine gold. Repeat this with the same silver a second and a third time, and you will always procure some black gold calx. In the first process, the particles, which are proximately fitted to become gold, begin to be perfect, and fall down as small black flocks. In the second, there are some more prepared and perfected; and in the third, none at all: when it appears, that the particles, fitted to become gold, are by the two first operations quite exhausted, or drained out of the silver.

Here it may be objected, that the regulus of antimony (*regule de Mars*) has produced or educed this black calx from itself: if so, there must as much be procured in the second and third operations as in the first: whereas in the second, there is not so much as in the first, and in the third, none at all. To this add, that we very often meet with grown, native gold in the earth, much paler than a fine sort should be, yet without yielding the least silver, and which, by a repeated smelting, begins to become perfect, and to attain its due colour. Thus we find in silver a matter that turns to gold; and in gold, a pale (blanchatre) matter, which by the fire gains the genuine gold colour. These are the two matters, which are a middle metal between gold and silver, but which remain not long in this state, being by each smelting brought still more and more to the perfection of gold *.

* Mem. &c, l'an. 1709. p. 142, seq.

This experiment afforded me a double pleasure ; *one*, as it is so much adapted to our present enquiry, and may yield no small matter of reflection to those, who, while they attend the business of separations, overlook that of introduction : *another*, and not the least circumstance, is omitted, but which is very needful for the information of the curious imitator ; especially as it attributes to the silver, what one might be apt to ascribe to the regulus. As in silver, not indeed in all, something may lodge, which by certain *additions*, may be educed from it, so the same may with probability be affirmed of ores : and here the *additions* may be made in three different ways ; either with other ores, with metals, with unmetallic earths, or with sulphur or arsenic, or both together, under a proper previous preparation : not to mention at present salts and sharp acid waters, which are foreign to our present design.

(1.) Ores may not be so well adapted, unless previously one of them be made recepible, and thus fitted and prepared ; or be, in regard to the two middle-minerals, sulphur and arsenic (the two grand mineralising matters) of a different nature and habitude : for, not only do those volatile bodies operate on each other, but the arsenic may, by means of its standing the fire longer, wait the desulphuration of any other ore, and into this introduce its own naked hungry earth ; unless by an undue degree of fire its efficacy happens to be destroyed ; or a fit metal lodging in the one, with which appropriated earths may be brought into mutual action, they are both lost.

(2.) I

(2.) I find metals better fitted for *additions* for *pyrites*, and these not so much in their metallic as earthy form, so they be otherwise adapted to the subject.

And, (3.) Earths seem of more importance than we commonly imagine, from the prejudice of considering them only as dead, inefficacious bodies: for, tho' we may not always allow them activity, yet a passive receptibility we often may.

I know of earths, not only devoid of all *gold* or silver, but of any other metal, yet combined with *pyrites*, yields silver in a proportion never to be found in *pyrites* alone. There are earths, looked upon as dead and effete, which in obvious circumstances, particularly phosphorus, manifest the greatest degree of activity. What are salts other than productions from earth, only that they appear not in their saline form in all operations: and salts and earths are ever mutually convertible; salts turning again to earth, as is a known case. And M. Rosinus of Munden sent me a white crystalline salt, greatly resembling a Glauber's or an Epsom salt, and prepared from a sort of stone, without the addition of any saline matter: which seems to be confirmed, from observing, that mineral bodies, manifesting nothing saline, as bismuth ore and cobald, much more *alum-shiver*, do barely by means of the air yield an actual salt.

These things being premised, we are to consider the *gold* in the *pyrites* in a threefold view:

(1.) As it is seen in the common way of proof, by means of lead and aqua-fortis.

(2.) As

(2.) As procurable by the aid of additions:

And, (3.) As an *over-shot*, or overplus, not discoverable in the common method of proof.

As to the first, I shall waive the questions relative to the presence and eduction, and only leave to reflection, why copels, that have been in use, and thus are become glazed with lead, yield upon re-fusion, more silver than the *lead-grain* of such lead originally amounted to; and whether ever any one assayed his lead for *gold*? The effects of lead and cupellation, are, certainly, considerable; seeing thereby, the noble metals are penetrated so much, that not the least of an ignoble sort can escape the action thereof, but must needs be discharged and expelled: and what a degree of mutual action and re-action must there not besides happen among the *pyrites*-particles themselves, either in the course of a roasting, or of the incocation itself?

With much more propriety may the question be urged; when *gold* is procured from *pyrites*, where, by the common proof, there is none at all, or in contradiction to it, an overplus is found: instances of which I could alledge from my own experience. And from hence we learn, if nothing else, at least here to distinguish what is possible in nature: and I have repeatedly said, that it is both possible and feasible to assist nature by means of *additions*, but not without labour and expence: yet after all the good hints I have here and there dropped, for working *pyrites*, minerals, and metals in this view, I cannot omit adding something further: as that the gold educed in the common way

way from *pyrites*, is never formally in it; seeing no one single metal is ever formally in any ore as such, or can be said to be in it in its metallic form.

Gold and silver can never be called *formal*, till they have attained their metallic form, and are thus become native, or, as we speak, *grown*; but the metal is to be considered in the ore no other than an earth, which either the sulphur, the arsenic, or both together, have penetrated, dissolved, and drank up; or which appears barely in the form of an earth or stone, without any observable sulphur or arsenic.

But now is this *gold* and silver earth, or calx, an actual metal? or more distinctly, does it already possess whatsoever is proper both to its ground-mixtion and metallic form? Must something be given to it, or taken from it? We have examined this above, on occasion of Becher's and Homberg's experiments; being much the same question, as might regard a metal reduced to an earth by art: and I must needs abide by Geoffroy's conjecture in opposition to M. Lemery: namely, that for the metallisation of a metallic earth, something, namely, a fatty, inflammable matter, must be incorporated therewith.

But lastly, how will the case hold with such *gold-earth*, as by peculiar ways and *additions*, must be educed from *pyrites* and other ores? There it lodges neither formally, nor in its ground-mixtion, but must first, by the operation, be reduced to a *gold-earth*. Yet there lodges somewhat, as a meal, in the ore or metal, which only wants a proper ferment, and a due degree of coction; and this ferment again is an earth. This earth appears to be

be in the silver of the *pyrites*; particularly from the consideration of the above-mentioned experiment of M. Homberg.

Yet, first, in regard to the origination of silver from *pyrites*, there remains the same difficulty, to account for the origination of *gold*. Again, we find, that where the most silver, there the least *gold* lodges: nay, the richest silver-ores, as the *glassy*, and *red-goldish*, contain not, at least with us, any the least *gold*; whereas the contrary would necessarily happen, if not always, yet generally, were silver as such, the mother of *gold*, or did silver contain the proximate matter of a *gold-earth*. And though native *gold* may lodge in *glassy* ore, it follows not, that this ore is the soil proper to *gold*; seeing matters, as has been often observed already, may, without the one lie near, nay, lie entangled in each other, being the cause or origin of the other.

Whence then are we to fetch our new-born *gold-earth*? To ascribe it to the iron in the *pyrites* seems improbable; as the pure *iron-pyrites* neither yields any *gold*, by the common proof, nor admits of any melioration from additions. To suppose it lodged in the copper of the *pyrites*, can with as little probability be imagined; for, tho' *gold pyritæ* are usually coppery, yet the *yield* in *gold* is not always in the proportion of the copper-yield; but the richest *copper-pyritæ*, and which on that score are called *copper-ore*, I have always found to come shortest in *gold*.

Of the crude, unmetallic earth in *pyrites*, we know not the nature and properties, except what I myself have negatively advanced about it, and its vitrescibility; no one else, so far as I know, having ever examined it, or once dreamed of its existence
in

in *pyrites*: nor is it so very easy a matter to come at the knowledge of it; as it is with difficulty, or not at all to be exhibited in a separated state, without any new mixtion.

Indeed, *gold*, as an earth, may lie in earths: and it is probable, that metals generally have their ground-earth from crude earths only, and attain their specification, or formality, from the nature of the *influent*, and the mutual action of the matters, and from the beds and matrices, their proportion and incidentality: in particular, *gold-earths* readily lodge in marly, quartzy, sandy, and consequently in vitrescible earths: so that this crude earth of *pyrites* bids fair to be a fitly appropriated soil for such conception and growth.

As to the efficacy of sulphur in that case, there certainly lies concealed great virtue, both in the whole and the several parts of sulphur, communicable by the operation; particularly in the metallic or copper portion thereof, which, according to Poppius's experiment, is capable of being volatilised and sublimed.

But, (1.) sulphur is not to be considered so much in a passive, as in an active capacity; not as receptive, but as impregnating.

(2.) I have experienced its activity, when properly applied to the incomplete, particularly the white metals and the semi metals, exerted more for the production of silver. Arsenic remains to be considered, which in this case, especially in conjunction with copper, is of some consequence: in it lodges an earth, a mercurial virgin earth, eminently suited for *gold*; as those but a little conservant with Mercury must allow; to which no-

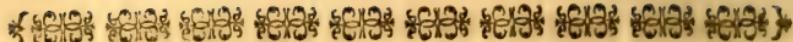
thing comes nearer in nature and virtue than arsenic. And I would fain know why, or whether by chance it happens, that the native gold in the ore of Goldesthal is never found near the yellow, but always near the white pyrites, nay, immediately fitting, and, as it were, glued thereon ; and again, why found in quartz among shiver ?

This *gold-earth*, which pyrites and other ores yield, as a formal gold, must doubtless be in proper weight and measure ; and that, should it belong either to the silver, the copper, or arsenic, not all the silver, copper, or arsenic, would turn to a *gold-earth*, but in a certain proportion what is fitted so to do. Whence I draw the following conclusion, comprising all I have hitherto said, and which deserves to be observed : that if this measured or proportioned quantity of earth be already proximately prepared, and such a *gold earth*, as only, like a *gold* reduced by art to an earth, wants the fatty proportion to its metallisation, it is educible by separation in the common way of proof, without any further treatment : but if not an actual *gold-earth*, but must first be reduced to such ; we cannot in that case say, *pyrites holds gold* : and should more than two different parts of *pyrites*, nay other foreign matters employed, contribute to the ground-mixtion of such *gold-earth*, we must the rather adopt the terms, *introduction*, *production*, *transmutation*, &c. and drop that of separation.

It need not be wondered, that I have dwelt so long on this question, as it includes another; viz. whether art may not become assistant to nature ? And so far as this last regards not only a matter of truth, but of utility too, so far does the other deserve to be

be examined into and cleared up. But should it at length appear to be a thing impossible to enrich ores and ennable metals, this use at least we may reap from it; *viz.* to learn not to throw away our labour and time to no purpose: on the other hand, should we find some degree of melioration attainable; this would not only encourage us for the present, but be an incentive to us for the future to proceed further.





C H A P. XIII.

Of the ORIGINAL PARTICLES, or of the
PRINCIPLES of the PYRITES.

WE have hitherto treated of the mixed and compounded parts of the *pyrites*, as (1.) its iron-earth; (2.) copper-earth; (3.) crude, unmetallic earth, with which the two first are ever entangled; (4.) its sulphur; (5.) arsenic, and the sandarach thence procurable; (6.) the silver; (7.) the gold in the *pyrites*; all these are to be found in the *pyrites*, though not in equal regard or consideration, some being essential or constituent parts, others incidental only, and without which the destruction of the whole either may, or may not be effected. The proper ground-parts are an iron-earth, and something that is volatile, and that either sulphur or arsenic; all the others, namely, the copper, gold, and silver, are incidental, as the *pyrites* is often found to be without them; but as the proportion of the copper is often found to exceed the iron-earth in weight, it is necessary to take a view of it in another light: yet, as the copper rises and falls, nay, may be quite wanting, it might indeed be removed from the class of incidental, and brought nearer to the first order of parts; but to distinguish it in some measure from the parts, both of the first and second order, it may be assigned a middle rank, and be called a secondary constituent part of the *pyrites*.

What

What we now propose is, in short, to learn what particles the iron, copper, crude-earth, sulphur, arsenic, gold, and silver in *pyrites* consist of. Speculatists, ever fond of enquiring into what is called the principles of things, may be apt to think we should have set out with, instead of having postponed 'till so late this enquiry. These preposterous enquirers into nature, ever at the entrance upon their disquisitions, fall to explaining the principles of their subjects, before they have once duly examined their mixt parts, much less their forms, proportions, habitudes, connections, divisions, productions, &c. To lay so great a stress on things quite out of the reach of our senses, as principles, in truth, are, and overlook what our senses are proper judges of, is but the high road to endless conceits and imaginations; one single proposition, fairly deduced from experiments, being far preferable to, and more valuable than all those imaginary theories, which have neither experiment, nor other solid foundation for their support: and though it may not be unuseful to reason about things, yet we should proceed in such a manner, that the reader may be led, as by a clue, from the proximate to the remote principles, from the mixt parts to the simple, and thus in a retrograde order, namely, that in which we treat the subject under experiment.

Now, if we would take all the parts educed from *pyrites* in the largest view possible, these either existed already in the mixtion thereof, and thus are actually separated, or are new-produced in the act of separation, or rather of the destruction of the *pyrites*, or else they existed in the *pyrites* in distinct parts; the former are iron-earth,

copper-earth, crude-earth, sulphur, arsenic, gold, and silver, all which we have again divided into essential and incidental parts: of the latter, or the parts new produced, we have only one instance, namely, vitriol, yet it may be queried, whether to this last sort might not be added sandarach, as sulphur and arsenic, whereof sandarach consists, essentially and corporally exist in *pyrites*, not in an united, but a separated state, though not coming up so fully as vitriol to the case. And it might be further queried, whether the gold and silver in *pyrites* were actually, or corporally and formally, tho' in a separated state therein, and not new produced, especially by means of *additions*.

Should we abide by the essential parts of *pyrites*, namely, the iron, sulphur, arsenic, also the copper, the *pyrites*, in the strictest sense, is not a *mixt*, or a body made up of simple parts; nay, not a *compound*, or a body put together of *mixts*, but a *decompound*, namely, put together of *compounds*; and accordingly the question should seem, not to regard the original particles of the *pyrites*, but the original parts of each part of the *pyrites*: but as this would carry us too far, and especially as I consider not these parts as such, but only as parts of the *pyrites*, we not only may, but must enquire into its original particles, as a compounded body; and *pyrites* being a *decompound*, the question is, whether the compounds, as the sulphur and iron were actually and formally present when the *pyrites* was formed, or whether these compounds first existed in the act of formation and production; or, what to many may appear more distinct, whether the formation of the *pyrites* be a *composition*, or a *mixtion*? where, by the former, the parts must actually exist, but by the latter first begin to exist.

We

We are here not to consider nature under the notion of a builder, who collects and prepares his materials, but rather as forming *mixts*, in the course of the composition itself; or, in the course of the decomposition, *compounds*; and, in the course of the formation, forming new materials, not existing before; and even by means of destruction, which readily happens not without new productions; though some, from experiment, might maintain the contrary: as it must be allowed, ore may be prepared and formed by art, from parts already mixt and compounded, as metal and sulphur, yet no consequence can be drawn from art to nature; though, so far should seem probable, that nature and art may proceed in the very same manner: and I have made several experiments, in the view of mineralising metals, which I shall here communicate.

A proper ore consists, proximately, in a metallic earth, sulphur, and arsenic (either one, or both together, of these two volatile matters) to which may be added a frequent admixture of an unmetallic crude earth; I mean such a crude earth as is incorporated with the mineralised metal, or proper ore mixture, and not a kind of stone and mineral adhering to the ore: I also do not mean ore in a lax sense, according to which, all sorts of stone, barren in metal, sulphur, and arsenic, are called a mineral, or ore: nor do I mean ore in the usual notion of miners, who stile silver holding *yellows* and *browns*, ores; but I intend such, where the metal is plainly and eminently seen mineralised, or reduced to an ore-state: or, ore in the strictest sense, is either a *sulphurated*, or *arsenicated* metal, as pyrites, lead-glitter, copper-ore, tin ore, red goldfish, glass, grec, and the like.

When I would try to make ores from metals, and, as it were, re-produce them, I cannot, for that purpose, employ the principles, or simple particles themselves, of which they are formed by nature in the bowels of the earth, as these, in their separated state, are no objects of our senses; but I am obliged to use metallic earths, or formal metals, also real sulphur and arsenic, in order either to arsenicate, or sulphurate the former, and thus bring them to the form of an ore. In some instances I have hit tolerably well, in some but indifferently, and in others not at all, as will appear from what follows.

(1.) From some universal earths, which neither are, nor were actual ore or metal, metals may be made; for instance, from fossile calamy, iron, indeed in no considerable, and zink, in a large quantity; not only when the proper body, wherein it may incorporate, namely, copper, is exposed to it, but even without the addition of metal, barely upon the application of the metallising, fatty matter, with proper care and attention, that the matters be not burnt out and reduced to ashes.

(2.) From metallic earths metals may again be made, and, in part, such as they already were, as from lead-ash, tin ash, &c. lead, tin, &c. namely, by re-incorporating the fatty, metallising substance, or *phlogiston*, which operation is called *reduction*; partly, what they were not before, as sufficiently appears both from gold and silver, which may, in different manners, be educed from different incompleat metals, and semi-metals, particularly, bismuth, tin, regulus, lead, and quicksilver.

(3.) From

(3.) From universal crude earths it is with difficulty that ores can be exhibited, the contrary of which one might be apt to imagine from the opinion of such earths being the *mother* of ores, and the sulphur and arsenic with their coction, the *father*, or impregnating principle. Examine the matter, as I have repeatedly done, but in vain, with sulphur, a thing otherwise powerful and efficacious, on well purified and prepared ochre, which already, along with sulphur, was an ore, that is, a *pyrites*; or if you suspect it fallen, by the vitriolisation, to a form quite irreducible and foreign to the design, take slime, marl, loam, clay, and leaving out the tenderest, unchangeable, and mildest earths, try any how, with sulphur, to accomplish an impregnation of ore: though it cannot be denied, that to the production of metals, particularly of iron and silver, by means of sulphur, not only the earth of one of its parts, namely, its fatty portion, but of its whole substance, is really fitted; as, by a due degree of appropriation and incalescence, it is not only made operative, but, by a proper length of time, may be made permanent; but this last operation requires the hand of an able master.

(4.) From some metallic calces, or earths, that were actually metallic, ore may be again made, as appears from the genuine *glassy* ore, which, from the saline silver-calx, when smelted along with sulphur, nay, softly, and for a continuance thoroughly warmed therewith, usually appears in a *drusy* form.

(5.) From silver itself, without previous reduction to an earth, there is again procurable with the addition of sulphur, or rather cinnabar (as the sulphur in

in the cinnabar has more time duly to lay hold on the silver) such a glassy ore, not easily distinguishable from a native sort; as appears from the known cinnabar processes, where usually filed silver is cemented with cinnabar.

(6.) Ores may be made from the incomplete metals, and from semi-metals, as tin-ore from tin and sulphur, antimony-ore from regulus and sulphur, bismuth-ore from bismuth and sulphur, cinnabar from quicksilver and sulphur, lead-ore from lead and sulphur, namely, where the sulphur is in separate parcels, conveyed on the metals in flux; and that the incorporated sulphur may not be forced off again, the mixture is poured out in due time. Yet,

(7.) It is from the fewest metals such ores may be made, as shall resemble those from which metals were originally smelted, *viz.*

(8.) A factitious tin-ore, which is flakey, blackish, footy, and stellate, like antimony, nature no where supplies us with, though properly to be called a sulphurated tin.

9. From tin (so far at least as I have tried) no tin-ore can be made; neither can its proper mineralising substance, the arsenic, be brought to flux, and consequently to the requisite degree of activity; nor the tin duly exposed and appropriated to it, on the score of its easier dissipation and incineration. As little,

(10.) Is a mineralised bismuth, or factitious bismuth-ore, found similar to a native; for, though it appears smutted by the sulphur, and looks fine, yet

yet it not only does not exhibit the texture, but even the appearance of the natural mixtion is wanting, by which it should hold no sulphur; though this experiment should, on other accounts, be repeated, and more accurately examined.

(11.) That procured from lead and sulphur comes tolerably near a fossile lead *glitter*, or ore; only it is very small grained, and, if not removed almost instantaneously from the fire, proves very footy and powdery.

(12.) The reduction of a metal to the form of an ore, even its native form, is better seen in antimony, which is procured from *regulus* and sulphur, but more fine grained than a fossile antimony commonly is; and would certainly be more coarse grained, if art, like nature, could take the proper time, and the operation not be hurried.

(13.) 'Tis in the preparation of cinnabar, that is, the mineralisation of quicksilver, that art, at length, most perfectly approaches to nature, insomuch, that between a factitious and a native cinnabar, very little, if any distinction appears.

(14.) On the contrary, copper cannot be mineralised, or not so as to be like a native ore, for that procured from sulphur and burnt or calcined copper (*as uatum*) is no longer a metal, only as it contains sulphur, it is called a mineralised copper; and, after burning out the sulphur again, nothing remains but a metal burnt out, and reduced to an earth; And where in nature do we find such a sort?

(15.) №

(15.) No genuine ore is procurable from iron, especially in the form of a *pyrites*; for, as to the factitious *pyrites*, for which antimony is employed, it is in parts highly antimonial, and thus of a mixtion unlike what is native, seeing antimony is never observed to be in *pyrites*; or, it will be a sort of scoriæ, or flags, where the iron, after the precipitation of the regulus, combines along with the sulphur, and exhibits something resembling an ore, without appearing yellowish, like an ore consisting of iron and sulphur, as in the *sulphur-pyrites*. Besides, in the absence of the salts it falls not to pieces, but remains firm and lasting; and yet it is affected by the air, though not in the way of vitriolisation, such as the air usually effects in genuine *sulphur pyrites*. We come still nearer to nature here, when for the sulphuration of iron, instead of antimony, we employ a pure lead-ore, under which operation lie concealed some practical truths.

Now it is possible there may be some better means of bringing metals and metallic earths back again to their native ore-form, as the ways of trial in nature are so endless, that it is not possible to devise, much less perform them all; we must not therefore, from a miscarriage in an intended experiment, directly conclude the impossibility of the thing: yet it follows not, that nature, in her formation of the *pyrites*, proceeds in the very same manner that art does; but, from the circumstances hereafter to be alledged, there is no small probability, but that to the ground-work of *pyrites*, as of other ores in general, not *mixts*, but *simples* or principles contribute; that is, not matters already proximately prepared for parts of *pyrites*, but undetermined

determined juices and damps, which, by their conflux and coction, first of all become either iron-earth, copper-earth, sulphur, arsenic, gold, or silver, as now extant in the prepared pyrites.

Upon a general view of the subterraneous ore-productions, particularly *druse* and *sinter*, we shall find three sorts of stone, and as many ways of their production and generation.

The first is an *induration* or condensation of dry, earthy, but tender, porous, and powdery particles, by which an earth may be baked, and become of the hardness of stone, by means of air and water, as I have reason to be fully satisfied by indubitable signs from the *ætites*.

The second is a *precipitation* of earthy particles out of water, by means of its running and trickling down, whence arise the *sinter flos ferri* and *staladites*; not out of muddy, but the most transparent spring-waters, in which the earth lies strewed up and down in the most tender manner, so as to escape not only the sight, but the closest strainers.

The third is a *crystallisation*, where stoney, both flinty and spathy particles, intimately dissolved and mixed in the water, like a salt, shoot out of the most transparent crystal waters, by means of rest, and by length of time; consequently, by the most leisurely and unobservable evaporation of the moisture into formal, saline crystals; as I have fully made appear in chap. V. In this also Dr. Woodward agrees, with respect to the production of *druse*, *mountain-crystals*, &c.

But

But as to ores themselves, it is not credible that any one of the above three ways is that by which they are generated : to begin with the third; we find, indeed, such, not only crystalliform, polygonal, prismatical, &c. forms, both in stones and salts, but also in *druse*, lying immediately on stone and bottoms, formed by crystallisation, as might incline us to think both the ore and stone to be generated at once, and in the very same manner. But it cannot be conceived also, that metallic earths, such as belong to the formation of ores, should be supposed to be dissolved by meer water, seeing we have neither example nor experiment to that purpose, as we have for the production of *druse*.

Why then must things, lying upon and near each other, be supposed to be produced together, and in one and the same manner? When *sinter* comes to settle, the *drifts* and shafts, where it is usually produced, are not full, but empty of water; but crystallisations happen not without water: and from thence we learn such apertures to be as seldom, after the generation of the *pyrites* on the *sinter*, full of water, as before in the generation of the *sinter* itself they could possibly be.

As little can the second way be genuine, whilst, as was said, common water is incapable of bearing up such heavy particles as the metallic are; I will not say in such a degree of dissolution and rarefaction, as there are no instances to support the assertion, but in such quantity as would be needful for the production of the supposed ore; seeing, by the least degree of rest, they should separate again like a slime or *sludge*. In a word, between water and a crude

crude unmetallic earth there may, indeed, be some, but between water and a metallic earth, no analogy; but the latter may by means of middle substances, *viz.* salts, as appears from the effects of sharp, corrosive waters on metallic earths, be appropriated to each other.

Lastly, as little can pure induration prove of any consequence here, if, amidst many other circumstances we again only consider the beds and figures of *pyrites* on *druse* and *sinter*.

But there are some strong reasons against imagining the generation of an ore to resemble the springing of a plant out of the earth; one is, that then we must expect to find in the stone or rock the roots, and, by their means, a connection of the ore with other matters, as its origin; but of this we find not the least trace either on *druse* and fissures, where they often lie as loose as if only glued thereon by one end, or in the firm rock or stone. But the generation of ores rather happens *damp-wise*, as I think I have shewn in chap. V. I shall only repeat one thing, that from hence, in particular, it appears, why the ores, standing on *druse*, generally present one side only, namely, where the *weather* or damp beats on them like a driven snow.

These ore-producing and ore-conveying *damps* may, both in their original and incidental matters, not happen to be of one and the same mixtion and influx; yet it is not so necessary to suppose a very great variety of them, seeing it is possible, from the internal coction, the length of time, the beds or matrices, to assign a reason, why from one and the same damps different productions may arise.

The

The beds or matrices are, undoubtedly, in some degree, pre-requisite; for, though almost each sort of ore be to be met with, consequently generable in various sorts of stone and earth, for instance *pyrites*, the universality of which is indisputable; *red-goldish* ore, which is to be found on quartz, spath, shiver, &c. lead-ore, not only in these, but in lime-stone, and other minerals; tin-stone in quartz, spath, Muscovy-glass, and clays; and we are still far from having made such discoveries in the bowels of the earth, but that many more may remain concealed; nay, probably, ores may be discovered in beds where they were never suspected to lodge, in particular, quartz, horn-stone, &c. which are the firmest bodies, prove to be universal matrices of ores: yet here it holds not as of the matrices of animals, which are absolutely necessary, and contribute materially to the birth.

This is manifest from experience: however the difference of beds may contribute something to the generation of ores; for, otherwise, why should *lead-glitter* be, if not quite a stranger, yet rare and thin sown in *shiver*, whereas *pyrites* is almost universal; and why should tin-stones never be heard of in *shiver*? But we are not always to form a judgement of the truth of this proposition from *mixt-work*, where ores and minerals are seen mixed together in a surprising manner; but then it is in places where two very different veins happen to cross each other.

In like manner, superfoetations must not be totally rejected, particularly, where ores and minerals are disposed in layers, one on the other; and where, not the undermost stone or rock, but each layer,

layer, must be considered as the matrix of the next above it. Besides, it is not to be denied, but that there are beds, or rather productions, where, according to all appearance, the under and over layer contribute neither positively nor negatively to the production of *pyrites*; that is, neither promote nor hinder it, but the *damps* contribute all; nay, even to the first earth of Becher, and thus to the ground-work of the ore.

Least of all is nature to be here considered as a common mechanic, who has all his materials ready prepared, and only puts them together: for, tho' the *gurs*, or mineral juices, and *sinter*, among which are claiey and ochry matters, are, and may be matrices, yet such marly, ochry mineral juices must not be supposed to exclude other earths and stones.

In a word, ores certainly have a matrix; first, a fitly adapted place; again, a matter not quite dead and motionless, but emitting its efficacy and emanations on something, or at least is a receptive matter. In and upon such earth and stone may ore and metal be produced, but neither can such earth or stone themselves turn to ore or metal; which matrix, whether the stoney or earthy, contributes more material damps, is a question not so easily resolved: the answer, however, seems to favour the last more than the first; as what is tender, soft, and yielding, is more fitted for the change happening here, than what is close, hard, and stoney.

But in all these *out-weatherings*, or exhalations, either from the under or upper layers, either porous, slimy or close; that is, either earthy or stony

S matrices,

matrices, the affair principally depends on the *in-weathering* or inhalation, for the production of an ore, particularly *pyrites*: which *inhalation* only consists in damps, fumes, vapours, &c. seeing, from the consideration of *druse* covered over with *ore* and *sinter*, neither induration, precipitation, crystallisation, nor vegetation, can have any place.

These damps are mineral, yet not of an ore and metal mixtion, but, proximately, fitted for such a mixtion. They must be of different forms and mixtures, consequently of different powers and virtues; as the busines of mineralisation cannot depend on bare coction, or the nature of the matrix or bed; namely, subtle earths, which, in certain places, proportions, times, degrees of warmth and coction, become in one place lead, in another tin, &c. and when once prepared, remain unchangeably the same, tho' indeed subject to *weathering* or destruction.

In general, mineral damps have the following origin and nature; they proceed from all manner of bodies, either animate or inanimate, though from the former in greater plenty; not only from porous and loose bodies, but also from the closest and heaviest bodies, even from firm stone, of which we have an instance in the magnet. Some bodies or matters evaporate, barely by a diminution and dissipation of their entire substance, as pure water, volatile salts, brandy, camphire, phosphorus, &c. Other bodies evaporate by an abstraction and separation of their highly subtle particles from the more close, coarse, and earthy parts; for instance, a saline or earthy water, either spontaneously or artificially. Others again exhale, by a destruction both of their texture and mixture; as appears

pears from the volatile salts procured from the corrupted parts of animals, and the acid of beer. This destruction is in the vegetable kingdom called *fermentation*; in the animal, *corruption*; and, in the mineral, I find no better term to express it by than *weathering*, or dissolution.

The matters considered as exhaling, are either purely watry, as pure water and brandy; or watry-earthly; as wine, beer, vinegar, oil, and slimy, saline, and bituminous waters; or earthy-watry, as wood, bones, gums, salts, sulphur, bitumen; or lastly, almost pure earth, if not entirely earthy, as crude and metallic earths, stones, ores and metals.

Now, as evaporation is a kind of motion, and motion implies an impulse; we here find as impellents, air and fire, which must animate, as it were, and make natural mixt bodies evaporate, or they would otherwise remain at rest and motionless. Air certainly is a capital instrument in the busines of evaporation, as being of itself not only sufficient, but better fitted for the purpose without actual fire; whereas fire cannot subsist without air: and the dissolutions, malaxations, separations, purifications, and new productions, &c. by means of air alone, prove quite different from those procured by fire. Yet air, which is in itself cold, and neither at all times attempered by the sun, nor by a particular sort of weather and wind, may be aided in its effects, when you would have it a proper, efficacious instrument, if not by an actual fire, yet by a due screening. The air operates from within outwards, whereas actual fire only externally: air also takes up more time, and thus makes purer and more lasting parts. It, indeed, carries along with it foreign

matters, but such as are more tender, flowing, and simple than the coarse, footy, stubborn, and earthy particles of fire, which in open or chinky vessels mix more of the flame with the subject. The principal effect of the air here is by its tenderly mixing the subtle, dry parts with the moist in a closer manner than can be affected by the fire.

In regard to mineral damps, particularly those for the formation of the *pyrites*, three things are to be considered.

(1.) Of what they consist.

(2.) Their origin, and the manner of it.

And, (3.) How they become *pyrites*.

As to the first, namely, in what the *pyrites* damps consist: we are not to suppose the universal air-particles, as the proximate matter and seeds; seeing this would be going too far back: neither on the other hand, are we to conclude them to be such mixtures, wherein the parts of the *pyrites*, namely, the sulphur, arsenic, iron, &c. are formally and substantially contained. But rather taking the mean, to suppose them to be damps of a middle substance, not common to all the three kingdoms, nor formal parts of the *pyrites*, but a kind of fatty, tough glue.

Here we must readily allow, (1.) That the proximate and first seminal forms of the *pyrites* may consist in crude unmetallic earths:

(2.) That crude earths are in their mineralisation and metallisation, primarily appropriated to iron, and

and secondarily to copper; as by destruction these two metals are usually very easily reducible to such earths; not but that they may degenerate (tho' not become of another species) from the unkindliness of the soil and other circumstances. And these damps are to be considered as different as the several *pyritæ* themselves are, and as universal as the *pyrites* itself is.

As to the second thing, namely, whence these damps, or the seeds of *pyrites* arise; we have three things to consider here.

(1.) Dry bodies, as earth and stone; only the parts of the former lay spongy and loose on each other, but those of the latter baked firm; and, at times, seem as if run or melted together: whence stone may be produced from earth, and earth again from stone. Now the question is, whether these last exhale.

We have three sorts of stone; namely, marl-stone, lime-stone, and flint-stone. Marl-stone, which has ceased to be an earth, and commenced a stone, not only crumbles in the air, but proves a good manure for vegetables; various instances of which I have mentioned in my *Flora Saturnizans*; particularly, one from Oberau in Misnia, which sufficiently shews the affinity between the vegetable and mineral kingdoms. But for this stone to contribute any thing to the growth of plants, it must be resolved, whereby the resolving moisture of the air does not so much crumble its earth, as rather extract something from it; not take it up as a fine powder, but swallow it up in such a manner, that the earth, by means of the water, is no longer an earth, and as little a water, but a third kind of

glutinous substance, arising from earth and water; which by vegetables is drank up in the way of a vapour: and the same matter, in order to serve to the growth of ores, must have both its first rise and propagation vapour-wise.

Crude, unburnt limestone seems also subject to *weathering* or resolution, and in the same manner: the *stalactites*, *dropstone*, or *stone sinter* of *Friberg*, to which the *iron-blooms* are also referable, is a sort of lime-stone. This limy substance is derived from a tender earth, sustained and carried along by pure water, from which it separates in proper time and place, and falling down collects gradually, and turns to the hardness of a stone. Now, as the water lets it fall, it is plain, it is something incidental to it, and something that it must have licked up somewhere in its passage. A like instance, not a little confirming this opinion, we observe sometimes on walls, plastered over with lime, as in large aqueducts; for instance, that called the *halsebrucke* at *Friberg*, and in those arches built in mines for strengthening *shafts* and *levels*; where it evidently appears, that the *sinter*, hanging down from these walls, comes from the lime; or rather, that the lime, even after being burnt, slackened, and no longer quick and capable of conception, is, notwithstanding, still fitted for resolution, and capable of being absorbed by the water in the tenderest manner; only with this difference, that this *wall-sinter* is not near so firm and hard, but remains always very spongy and flaky. Now, here we cannot so very expressly aver, that such earth is loosened by a *weathering*, and afterwards incorporated with the water; but that this rather happens, as we must at least allow of *wall-sinter*, by means of a soft flooding; tho' in regard to the genuine groove-drop-stone, from its particles being so intimately mixed with the wa-
ter,

ter, as by a kind of extraction, there must be a weathering or resolution to precede the flooding and extraction. Yet, amidst all our uncertainty about this matter, we observe lime-stone to be subject to destruction and resolution, from which come highly subtle earths, which, as here, may change to a formal stone, and in other circumstances, to different other productions.

The nature of *quartz*, or flint-stone, seems entirely impregnable and lasting; yet those *druse* and *quartz*, which appear, as if gnawed and nibbled by mice, seem to admit our calling their indestructibility in question: and, I must own, this sort of stone may contribute something to the production of ores, as it is so eminently adapted for that ground-earth, called the stony and vitrescible, by Becher.

(2.) In the depths of the earth we have collections of slimy, sulphureous, and saline waters, whence damps, vapours, and exhalations may arise, which may greatly contribute to the production of ores; from an internal incalescence and fermentation, as it were, these matters exhale, and in conjunction with other vapours, become proximately adapted for the generation of all manner of minerals.

(3.) Ores themselves exhale, of which we have palpable instances, tho' my experience extends only to four sorts, which exhibit any such change on the surface of the earth.

But this is not required of all; seeing (1.) several sorts of ores may be produced, tho' not several bodies, *weathered* or resolved for the purpose: as the resolution of a *red-goldish* ore is not requisite to the production of an ore of that sort, but a quite dif-

ferent sort, according to circumstances, may be produced from the damps arising from this ore.

(2.) As in the bowels of the earth, quite other causes and circumstances may concur, by which all ores, and such as we find unaffected at the day, may become subject to *weathering*.

Now the four, hinted at above, are alum-ore, cobald, bismuth-ore and *pyrites*,. Cobald, when exposed long in the heap, either in a close, damp, moist room, or to the open air, rain and sun, especially in small pieces, or a meal, becomes so heated, as to emit a sharp, sweetish damp or vapour from it. Hither also bismuth-ore is referable, which not only generally adheres, but is also nearly allied to smalt-cobald, and usually bewrays its *weathering* among cobald, with an efflorescence of a peach-bloom colour. Alum-ore, particularly the sort of a woody original, and still containing woody matters among it, and of a bituminous nature and quality, as the large alum-mine at Commodau in Bohemia, which takes fire in the air, after lying a little exposed on a heap in the weather and sun; so as not only violently to fume, but also turn to a coal, and burst out into actual flame; for which reason it must be often dashed with water. Stone-coal, so far as it is genuine, and not consisting in bituminous, light, aluminous matters, has not, so far as I know, the same effect as this alum-ore. And the question is, whether such accensions in coal-pits are spontaneous, or heedlessly caused from actual flame and fire.

Limestone appears, as was hinted above, even in its unburnt state, to be fitted for *weathering*, and to bear something to be extracted from it, communicable, if not to the air in form of a damp, or vapour,

pour, yet to the water, running over it. Again, it shews, that in calcarious hot-springs, it may be burnt by subterraneous fires even in the bowels of the earth, and thus communicate itself not only to the intercurrent waters, but probably, as in slack-ing quick-lime, may emit a saline, earthy fume, fitted here and there, especially with the acid of other vapours, for all manner of mineral produc-tions.

Pyrites is, preferably to all other sorts, capable of manifesting the subterraneous *weathering* of ores; yet the white, or poison *pyrites* is incapable of any such signs in the bowels of the earth, or by any experiments in the huts, like what we observe of the yellowish and yellow. The coppery sort, it is true, will not easily fume or exhale at the day, unlesf it be made very small, and lie exposed in large heaps in a proper place to weather and sun. But the coppery waters in the grooves, having their original only from resolved *pyrites*, shew also that *copper-pyrites*, especially in the bowels of the earth, and under certain circumstances, is liable to destruc-tion or resolution.

These waters, which are commonly called *ce-ment-waters*, are not only observed at Neusol in Hungary, but also in many grooves with us at Fri-berg: and it would seem to me, that the more coppery the *pyrites* are, in which case we at Friberg usually call them *copper-ores*, not *pyrites*, the less yielding they are to such *weatherings*, and the fir-mer and more constant they remain; whereas the less copper the *pyrites* happens to hold, and the purer they are in iron, it more easily vitriolises; besides, that we have fewer instances of such vitrio-lic waters, but many of springs, holding pure iron-

iron-vitriol; as the *iron-pyrites* is not only the most common sort of *pyrites*, but of ores too; so that, preferably to other minerals, it should seem to be serviceable for yielding fumes and damps for the production and generation of new ores.

3. Some other circumstances are here to be considered, by which we may have a nearer view of the manner of *pyritification*, or mineralisation in general.

(I.) We are not to imagine these ore-damps, which at length end in the form of the *pyrites*, already to contain the parts of the *pyrites*, as iron, copper, sulphur, and arsenic, but only to consider them as a seed. This is matter of fact; the proof clearly appears from the enumeration of the several circumstances above, therefore I shall only mention the texture of this ore, which is so smooth and even, so undistinguishable, so uniform in the mixtion of its parts, as if run or cast together, and hence in its ground-work, of the most tender mixtion, and such a form, as can never be imagined of damps, containing the parts of the intended whole, without forming too gross a notion of the mineral principles.

Yet this comparison of animal and vegetable seeds must not be carried too far, as if the body of the *pyrites*, grown from its seed, could from its own substance enlarge and encrease: but here happens, first, an accumulation, in the course of which, an elaboration commences at the same time; by means of which the matter gradually approaches to the intended body; and so long as it is still receptive, or if you had rather, seminal and soft, so long it still receives the transient damps, which

which it brings into the same ferment and coction with itself ; and when the body begins to be compleated, which happens from within outwards, it ceases to receive any thing further, till at last it is arrived at its state, or full degree of perfection, and is, as it were, finished. Nor ought we more readily to believe *pyrites*, or any other ore, once arrived at their consistence, firmness, and state, to improve further ; for instance, in gold and silver-yield, all further working is at an end, and the body continues at rest and at a stand. An ore, it is true, begins again to come into motion, not indeed for its melioration and exaltation, but rather destruction and resolution ; as I mentioned above, and shall still further prove in the following chapter.

What has hitherto been said, may seem sufficient on the head of the *original particles* of the *pyrites* ; as being matters quite out of the reach of our senses, and in support of which we can have no convincing proofs ; but the whole must be made out by distant inferences and reasonings, and a good share of imagination : nor can any very considerable use be expected from them : yet, I cannot omit taking notice of two objections, for the sake, at least, of obviating some prejudices, and making some remarks, that may not be altogether unuseful.

(1.) It will be asked, how water is capable of such mighty effects, and the moisture of the air, which is nothing but a pure water, of dissolving, corroding, and *weathering* stones and ores ? I might only, for answer, direct the objector to the *pyrites*, which may be seen to crumble and vitriolise barely by means of the air, without any sharp, corrosive waters : but here I cannot forbear advancing

cing an useful truth, regarding the very mystery of the art, without engaging now in tediously enumerating what experienced men have boasted of common water, or rather, of what only appears to be such ; for instance, Becher, of a water drawn off from fresh clay ; Cassius, of the phlegm of aqua-fortis ; others, of that from vitriol, rain, dew, and the moisture of the air ; or without mentioning the power of the air, in regard to its effects on the animal and vegetable kingdoms.

This *truth* may be supported, that genuine solutions depend not so much on strong corrosions, as on gentle macerations ; that is, such solutions, as shall yield us any new extraordinary productions ; as it cannot be denied but that corrosive waters may yield something worth the trouble, tho' nothing extraordinary. Now, the less corrosive the means of solution are, the less of a saline nature they must hold ; and the freer they are of that, the less violence they exert on, and the more they are adapted, softly and naturally, to macerate the subject ; and to this we should bend our chief regards.

Thus, between solution in general, and maceration, there is a wide difference ; in regard, that the latter is always a solution, but the former not always a maceration. In a solution by corrosive waters, the *solvent* and *solvend* become indeed one body, but not so closely united, as in maceration ; for, by maceration, the *solvent* is so intimately combined with the *solvend*, as not only to become together an indiscernible body, but also to acquire a new form and nature. Yet the moisture of the air (tho' the offspring of other waters) has something peculiar, and should indeed seem, as it is saline, to have the effects of saline solvents : but properly

perly and formally it holds no salt, and if any be procured, it must be by means either of corruption or fermentation ; and thus, by means of the destruction and transformation of the *mixtion* ; or by means of a magnetism ; and hence it is at various times of various forms, according to the nature of the body it happens to be incorporated withal.

The incomprehensibility of the volatilisation of earthy particles may be objected, against what must happen in the *weathering*, or destruction of ores for new productions : but here we must not understand an evaporation in an earthy form, as what might well be allowed to happen, tho' not prove of any service to the busines of the production of ores ; but an evaporation in the way of a clammy, fatty, viscous fume, wherein the moisture has intimately drank up the earthy part. There may be intended in general a volatilisation, of dry particles, either by the power of nature or art, yet we are well to observe, that there is a wide difference between undertaking such volatilisation with a body, as standing in its natural crude union with other things, and as separated from them. *Poppius on Agricola* has proved the presence of real copper in sulphur, and I myself have discovered formal iron in crude sulphur. Have we not here therefore a volatile copper and a volatile iron ? But take and try your copper and iron, and you will find such volatilisation a very difficult matter, or not to succeed at all ; whereas such metals, whilst still lodged in *pyrites*, volatilise without any art, barely by the act of desulphuration ; and nature may carry on her processes in such places, seasons, and other circumstances, as are quite out of the power of art to command. To come nearer to our subject, we know

know the principles of the *pyrites* to as tolerable a degree of certainty as is possible, but to pretend to shew them in glass-bodies or cucurbits, and thus resolve the *pyrites* into these principles, and make them the objects of our senses, is what I despair of ever doing.

I am, however, apt to think, my notions about the *original particles* of *pyrites* and ores in general, may go as far, if not farther than those other principles; namely, salt, sulphur, and mercury, æther, and air, globules and *striæ*, or acid and alcali, &c. As to running mercury, tho' no metallic principle, yet I believe it procurable from *pyrites*. Mr. Boyle tells us, that some choice English marcasites being worked, in order to assay them for gold and silver, did, without any mercurial *addition*, yield some mercury *. This may well be matter of surprize, as it may be what does not always happen: but, when I come to consider arsenic, as a substance certainly mercurial, and that it only wants to be made fluid, I see nothing uncommon in all this. I shall say nothing of the acid salt of sulphur, as what, among all the volatile things, comes the nearest to quicksilver.

We have also experiments of some mercury being procured from oil of vitriol. Now arsenic lodges in almost all *pyrites*; in a large quantity in the white; in a less proportion always in the yellow, and often in the yellowish. Probably, the above marcasites were yellowish, as the yellow do not so readily appear marcasitical, that is, cubical: and the white, tho' such a figure be not uncommon to them, are not commonly called marcasites. And probably, the yellow and white may be fitted for
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* Boyle on the producibility of the chymical principles.

mercurification. But, whether the arsenic, after separation from the *pyrites*, that is, in arsenic-meal, fly-stone, or crystalline arsenic, be fit for this purpose, I leave those to determine, who consider incidental circumstances and appropriations, as so many empty notions, and who understand not the importance of the difference between bodies, as still in their native mixed state, and as in their separated.

With respect to the question, whether sometimes ore-veins may be found, where the ore-production is in *fieri*, and not actually formed : if this be understood of the accumulation of ore, there is no manner of doubt, but that ore is produced on ore ; and a vein, a fibre, may be so filled up as to receive neither this nor any other sort of ore-damp ; and thus the vein, that hitherto was but in *fieri*, comes now to be compleat. But ore is certainly generated, and that *damp-wise* ; but damp-wise productions imply surely an accumulation. But should the question regard the ground-mixtion of the ore itself ; the most experienced can neither shew the places and nests, where the ore-forming spirit broods, nor the ore in its eggs and seeds. Further, neither can the *gurs*, or metallic juices, whether from destroyed *pyrites*, weathered ores, or from macerated, luty, marly, slimy, spathy, and calcarious stones and earths, claim any place here. And tho' in this case our want of experience is to be lamented, yet it is probable, that after all our enquiries, we shall find neither eggs nor brood, but be forced to own, that *pyrites*, and all other ores, do in the course of the conception, or of lodging the ore-damp in its matrix, arrive to their perfection by a speedy coction and maturation ; if the accumulation itself be not the mixtion.



C H A P. XIV.

Of the VITRIOL from the PYRITES.

THE title of this chapter may, to many, appear strange, particularly to those who hear mention made of *vitriol-pyrites*, in contradistinction to *sulphur-pyrites*, as we allow not *vitriol* the title of an essential, constituent part of *pyrites*, but only a new production from it. *Vitriol* is, indeed, a body formed from *pyrites*, its parts, though not united in the form of *vitriol*, existing in the *pyrites*, and forming *vitriol*, without the accession of any other foreign body: for, though *vitriol* be not usually produced without the action of the air, yet the two essential parts of *vitriol*, namely, the sulphur acid, and the metallic earth, actually exist in the *pyrites*. This *vitriol* production commonly happens in the very same process whereby the sulphur is procured, though it usually happens without any desulphuration, even spontaneously: but as many *vitriol* productions have desulphuration for their proximate ground or basis, so as not well, nay, not at all to happen, especially at the day, without the former following it, the busines of *vitriols* cannot well be omitted, especially as it gives much light towards a better knowledge of the nature of the *pyrites*; though I cannot be so full and explicit as I could wish, for want of proper experiments, and can now only touch on the principal matters, reserving a fuller account of this incomparable metallic-salt for another opportunity: I shall, therefore, with all the brevity

vity possible, consider three things, (1.) the nature of vitriol, (2.) its kinds, (3.) its production, from all which will plainly appear the justice of my title.

(1.) *Vitriol* consisteth absolutely in an acid salt, and a metallic earth, both which are, by different methods, to be procured from it; the principal of these I shall only touch on.

Under the acid salt we are not to represent to ourselves something dry (and yet, what is sulphur more than a concentrated *vitriol-acid*?) but something fluid and aqueous; though the dry form of acid salts be no impossible thing, having, in an uncommon manner, shewn it from spirit of nitre and spirit of tartar, for exhibiting a pure, acid, dry, volatile salt. It may be separated from its *vitriol-mixtion*, either, as is usually done, by distillation, at first coming over in a white aqueous form, called *spirit of vitriol*, then in a thick, heavy, yellowish, and somewhat earthy form, under the appellation of *oil of vitriol*; or procured by means of an intermediate, namely, a lixivious, body, whence arise the known medicinal salts, *tartarus vitriolatus*, *arcanum duplicatum*, *sal mirabile Glauberi*, &c. with this remarkable difference, that it is not again to be forced out of the alcali, in the same manner as from the metallic earth, without becoming again, by means of a new intermediate body, a formal sulphur; when it exhibits either a *spiritus sulphuris per companionum*, or a *vitriol* again; as from sulphur it suffers itself to be incorporated with a metallic earth.

Next to sulphur and *vitriol*, it lodges chiefly in alum, in which it has received its body from a

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fatty, bituminous mineral; as may be seen, in particular, from the woody alum-ores of Commodau, the shivery ores of Schwemsel, and the earthy of Belgern; but, as appears from its resolution, alum possesses it in a quite unformed, white, stubborn form, most probably referable to a calcareous sort. It sometimes acquires, in distillation, a foreign, either a vegetable or animal fattiness; as, when in the course of the operation, the vessels happen to have cracks, through these the fattiness insinuates into the work from the fumes of the wood or coals, or when with design something inflammable is added, and then 'tis called *spiritus vitrioli sulphureus*, as the acid *vitriol* salt, and the phlogiston, exhibit therein something sulphureous.

The metallic earth of the *vitriol* is procured either by means of distillation, and remains like a brown-red powder, a *caput mortuum*, at the bottom of the retort; to which head also belongs the calcination of *vitriol* in other vessels, and for other purposes: it may also be obtained by means of precipitation, which is performed by an alcali, but, at the same time, earthy particles precipitating out of the alcali, a pure metallic *vitriol-earth* is not procured.

In this earth, after distillation, something lodges that may be extracted with hot water, and has the form of a white salt, called *gilla vitrioli*; not to be considered as a third constituent part of *vitriol*, nor as the *vitriol* itself employed, but as something different, a more elaborated, and thus a whiter *vitriol*; in regard it, in part, still consists of the same acid salt as was already drawn off from *vitriol*, and also it contains a portion of metallic earth,
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for the most part coppery, whence it is used as an emetic, and called *vomitoria*; I shall not assert that its contents are also somewhat aluminous, having not examined it thoroughly, though I have often suspected it.

That the *vitriol-earth* is metallic, and this always without exception, its metallisation clearly shews, as being performable by addition of inflammable, fatty things, nay, often happening spontaneously; when, for instance, the retorts, in the course of the distillation of *vitriol*, happen to have cracks, through which the fatty, fiery particles mix with the earth, which is in the highest glow, and thus fitted or appropriated, actually refund a degree of metallicity, and form an iron, as once happened to myself from a certain *vitriol*; the iron not only appearing by the magnet, but to be shewn corporally.

The proportion of these two parts in *vitriol* is generally the same in all, namely, in a pound of a fresh uncrumbled *vitriol*, commonly from ten to twelve loths, and thus full a third of metallic earth; four loths, or about an eighth of acid salt, or highly rectified oil of *vitriol*, including what is collected from the gentle evaporation of the spirit, and from sixteen to eighteen, that is, a compleat half water, or phlegm, not omitting what is wasted by the foregoing open calcination, or rather drying, in the air.

The reason of their inconstancy in the yield of metallic earth, is to be ascribed either to the difference of, or admixtures in, the *vitriols*, or to the evaporation and coction of the *vitriols* themselves; since many *vitriols* possess a copper and iron earth

at the same time, and that, occasionally, in quite different proportions; but *iron-vitriol* and *copper-vitriol* do not agree in one and the same yield of metal: and 'tis well known, that crystalline salts, when passing through sudden evaporation, and quick crystallisations, are always more watry than others, worked flower, and more leisurely; and these last, as being closer, more saturated, and rich in colour, are prepared by dyers, and the like sort of people, especially if coppery.

The form or nature of the *vitriolic* texture and cohesion, is perfectly saline, and therefore *vitriol* is justly called a *salt*, and, to distinguish it, a *metallic salt*; for, when pure and fresh, it appears transparent; moreover, it is on the tongue a saline, sharp taste; lastly, it is not only the being perfectly dissoluble in common water, so as the water shall remain clear and transparent (unless the air and warmth happen to dry it up, when such a solution is apt to let fall something undisolved, and the water to remain a small time turbid) but it also passes with the water, in its entire mixtion, quite through the closest strainers.

Yet, under the title of a metallic salt, we are not here to include a sort, parable, or rather separable from metals themselves, without the addition of any thing foreign, and consequently without the sulphur-acid, a distinction fully made out by Dr. Rothe, in his dissertation on *metallic salts*; neither are we to judge of it by the standard or scale of acid and alcali, as in the artificial exhibition of *vitriol* from its acid salt and iron, there usually happens an effervescence and incalescence by means of these two parts: nor can we admit, that because alcali's effervesce with acids, all bodies

dies manifesting such an effect with acids, as metals do, are and must be alcali's.

True it is, acids stand opposed to alcali's, and are of a quite different mixtion from them; but let us only represent to ourselves the incalescence happening, under a due treatment, between quicksilver and leaf-silver; here we have neither acid nor alcali; and yet the union happens with an effervescence: and what is still more remarkable, no such effect appears with filed silver, which is equally a silver with the former, even though the same quicksilver be employed; so that we see this effect is only owing to external, mechanical causes, the silver being beat thin, becomes the more exposed to the action of the quicksilver, and thereby rendered more receptive, as the latter may, with more quickness and briskness, lay hold on the silver, and thus, from a sudden brisk action and re-action, an incalescence must ensue, which in a flower degree thereof cannot.

The appellations given the several parts of *vitriol* seem in general proper. The acid salt, which commonly appears in a fluid form, lodges either in a water, and then it is called *spiritus vitrioli*, or in a thick liquor, and then called *oleum vitrioli*, or it is sulphureous, when it gains the appellation *spiritus vitrioli sulphureus*, or *volatilis*, or it still lies at rest in a metallic earth, and then it is denominated *gilla*. Now here the several appellations exhibit something different, and so are neither superfluous, ambiguous, nor equipollent.

The *vitriol-earth* is either yellowish, or of a brown-red cast; the yellowish is, either a *sulphur* or *orange-yellow*. The *sulphur* yellow is, in the first

place, both what precipitates in the boiler, and what afterwards falls down before and in the act of crystallisation, also what precipitates from the recrystallisation of a *vitriol*; though none of these properly deserve the name of an earth, or ochre, as they still retain much acid salt; and further, such earth as spontaneously precipitates from *pyrites*, particularly the arsenical, or white sort, after corrosion or maceration by sharp waters. The *orange*, or *yelky yellow*, is principally found in the earth in chinks or clefts, under the names *gur* and *finster*; also in many springs, particularly the medicinal, in *thermae*, in *vitriolic* or acid waters; and from *vitriol* itself, when not burnt quite to a redness. Hither also is referable, on account of the name, fossile ochre, or *mountain-yellow*; this yellow earth, used for colouring, containing also something of a *vitriolic* earth; hence it also yields some metal, but such as is not derived from *vitriol*.

As to the *red earth* of *vitriol*, it is called the *caput mortuum* of *vitriol*; not as if it was quite *yieldless*, since it not only contains the above *gilla*, but also metal, and that plentifully; but rather, as by the strongest degree of fire, it is deprived of its saline, *sapid* parts. It is now, as it was long ago, called *colcothar*; others denominate this *vitriol-earth*, *copper-red*; so far indeed not unjustly, as *vitriol* is commonly called *copper-water*, or as copper appears red, tho' not fundamentally enough, in regard this *copper-red* is often an iron-earth; and though it were a copper-earth, yet the former is always a beautiful red; the latter, on the contrary, a dirty and black red, nay, usually appearing entirely blackish. Further, it is called *red vitriol*, or *atramentum rubeum*, but as it is only in part, and not entirely, it deserves not the appellation, *vitri-*

ol; though others would by it understand, not a thing burnt, but a fossile matter, namely, a red *vitriolic* mineral, and would mean by it the *chalcite*s itself, though not so properly to be called a red *vitriol*, as a red *vitriolic* mineral: we also find it called *rubrica*, which is to be distinguished from the *rubrica fabrilis*, or *scriptoria*, [ruddle] used for drawing and writing.

In short, the highest acid in nature, and a metal, are what constitute *vitriol*; the resolution thereof evinces this truth plainly enough, and the composition confirms and puts it beyond all doubt.

Vitriol bears a great many names. *Vitriolum* seems to be derived to it from its glassy transparency and splendor. *Atramentum* is another appellation formerly much used. *Chalcanthum* was the common name among the Greeks, denoting properly a *copper-vitriol*, or rather, flowers or efflorescences from *copper-pyrites*, or ores, under which they must needs have comprised the *fideranthos*, or flowers of iron, or rather the efflorescence of *iron-pyrites*, as they made no express mention of *iron-vitriol*, tho' in fact, the latter is more plentiful than the other, and its *pyrites* vitriolizes sooner. Such are the most common appellations of *vitriol*.

(2.) Under the head of the kinds of *vitriol* we find a great deal of ambiguity, confusion, and contradiction, from the several appellations, *Sory*, *Misy*, *Melantaria*, *Chalcites*, *Atramentum*, &c. which authors give us as the names of so many distinct kinds. *Misy* is said to be a yellow *vitriolic* concrete. M. Lincke sent me, from the Hartz, a fisken-yellow, clear, flakey, powdery matter, under this title, consisting, indeed, of martial *vitriol*,

but in itself, or rather its flakes, containing somewhat of a foreign earthy nature, which, for want of a sufficient quantity of it, I could not properly examine. As to the *etymon* of the word, I am apt to think it derives from Mysia, a country in the lesser Asia, and denotes a Mysian *vitriol*, and that its first description was taken from something external and incidental, namely, its yellow colour. *Sory*, doubtless, derives from Soria, or Syria; and as the first *vitriol*-ore from that country appeared externally, in its roughness and matrix, of a dark-grey, its description was founded on that circumstance. *Melanteria* should, from its *etymon*, seem to denote a black *vitriolic* concrete. *Chalcitis* is, by some, held to be a red, by others, a white *vitriolic* concrete, and really is no other than a woolly and capillary sort, and consequently a white efflorescence. Now, it is true, we have such efflorescences of a real white colour, and that on a red mineral, whence *chalcitis* is denominated red, and this is the genuine white *vitriol* mentioned by Lohneiss; seldom found any where, and with us at Friberg, not at all.

But we are to guard against taking it either for the *trichites*, or capillary *vitriol* in general, which only appears white on account of its tenderness, but which, by a due crystallisation, plainly enough shews its green colour; or for the aluminous efflorescences, appearing among and near *vitriol*, on aluminous, *pyrity mixt-work*, as is that of Braunsdorff: moreover, writers seem to mean by the *calcites* a *vitriol* calcined to whiteness. But the prevailing opinion is, that among the ancients it denoted a *vitriolic* red mineral. But whether white or red, native or artificial, it must needs have been an iron, and not a copper *vitriol*, as having been used in making their mithridate.

In short, all the abovementioned are certainly *vitriols*, and *vitriolic* mixtures, though no one of these titles is properly expressive of their nature, all of them meaning only something incidental. *Chalcitis*, in its proper signification, which yet is not the common, should denote a copper-ore, or copper-stone; but being now described from its earth or stone, and its red colour, it is, insomuch, referable to the incidental description of the others.

As to *sory* and *melanteria*, I find such *pyrity*, *vitriolic*, dark-grey *shiver*, not only in the grooves, but also at the *day*, after having lain there exposed for some time. Hither also may be referred the *vitriolic-sory*-earths from other places; though under this appellation, Galen only mentions a firm stoney matter; as M. Berger *, in his treatise on the Carlsbad waters, mentions such a sort seen at Siena in Italy (so also does Matthiolus, in his commentary on Dioscorides †) and compares it with the *vitriol-earth*, near Schmiedeberg in Saxony: and as to *misy*, we find it often repeated, that *sory* changes to *chalcitis*, *chalcitis* to *misy*, not only by Caneparius, but also by others; by *chalcitis* not meaning a crude, red, *vitriolic* mineral, but the *vitriolic* efflorescence itself. 'Tis true, a black *pyrity* mineral gives forth a white *vitriolic* efflorescence, which, at length, turns yellow: nay, a *vitriol*, whether naturally green or blue, does, by means of a warm air, or a soft fire, not only crumble to a white powder, but also this powder, both superficially, and at last throughout, turns of a yellow cast; 'till at length, by heightening the fire, it is all changed to a red powder.

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* Bergeri Commentat. de Therm. Carol. p. 197.

† L. v. c. 74.

Yet this *gilding* happens not so well in the groove, as at the day, unless there happen to be there dry places, or warm weather. From the Rothe-grube, at Friberg, I have procured much of this black-grey vitriolic mineral, where, indeed, the *mify*, called the uppermost zone, or layer (*zona suprema*) of the *atramentum metallicum*, was always wanting, but soon appeared again, upon exposure, for a little time only, in some degree of warmth. And at Braunsdorff, a mile from Friberg, I have taken up a black shivery rock, in which I have observed both *chalcitis*, called the middle zone (*zona media*) and *sory*, called the under zone (*zona infima*); nay, after repeated elixations, being kept for a few weeks under cover, it was again found over-cast with white and yellow, but with this difference, that it proved a good, or, generally, a pure iron-vitriol, as was that from the Rothe-grube abovementioned, in the open air, not so much yellow, as white; but if mixt, as was that of Braunsdorff, and in particular aluminous, the yellow soon shews itself in the same air as that in which I lay the piece from the Rothe-grube: but in a warm room, especially if placed near the fire, *vitriols*, whether of one sort or another, pure or mixt, do, at last, all of them turn yellow; nevertheless I have not been able to observe any orpiment, consequently nothing arsenical in what so easily, even in the cool air, as that of a cellar or vault, turns to *mify*, though I have carefully examined it, as many others, and I myself at first might imagine; especially as the Braunsdorff pyrites-work readily does, and is really very arsenical, of which hereafter, in particular, when I come to examine the question, whether arsenic contributes to the *vitriol-mass*, as such.

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The *atramenta*, atrament-stone, or atramentore, in a lax sense, denote all sorts of *pyrites*, so far as they yield *atrament*, or *vitriol*, for making ink, or a black colour; but in particular, a certain mineral, or stone, in which *vitriol* formally lodges, only intermixed with earth or stone. M. Linck has furnished me with two samples of it, the one from the Rammelsberg, the other from M. Baier, professor at Altorff, which indeed differs a little in colour from the former, though it may be allied to it. Both of them not only yield a *vitriol* directly in water, but also entirely crumble to a brown-red earth; yet whereas the last sort tinges iron of a copper-red, but the first does not exhibit the same appearance; and whereas the former manifests some alum, the latter, none at all; and whereas they are properly not a stone, but a concrete, rather of *vitriolic* earth, as appears from their falling to pieces in water, it will be no ways improper to suppose them a hardened earth, and either formed from *weathered pyrites* entirely, or, from the *vitriolic* waters, derived from *pyrites*.

Vitriol may be classed (1.) with respect to its internal essence or nature (2.) its colour and form, (3.) its origin, (4.) its use.

(1.) As to its essence, or nature, it always has for its basis a metallic earth, and that either an iron, a copper, or both together; of these, either separately or combined, with the conjunction of the sulphureous acid, vitriol consists: if of iron, it is called an *iron-vitriol*; if of copper, a *copper-vitriol*; but if of both together, it may properly be called a *mixt vitriol*. To this last may be referred the *white vitriol*, which, besides its portion

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of iron and copper, seems, though I cannot positively say it does, to partake of something aluminoous. We have few instances in the grooves of a pure, simple, either martial or venereal, *vitriol*; and when we would have it pure, the most careful methods of refining, evaporation, and crystallisation, must be employed; or, which is the surest method, the *vitriol* is to be prepared originally from its metal, either iron or copper: and that, both from the nature of the *pyrites*; not only in themselves, or as *vitriol matrices* in their mixtion (as being seldom pure irony, though the iron generally predominates, nay, is often the only metal in them, and a *copper-pyrites*, even that sort, on account of its rich copper-yield, called a copper-ore, is never without iron) but also from the nature of its encompassing rock and stone; in particular, the black, fatty, and shivery sort, as matrices of the *pyrites*, wherein there is generally, at the same time, alum generated: whence also the famous Hessian iron-earth is not always naturally pure in iron-*vitriol*, but often yields actual alum, which must carefully be parted from the *vitriol*.

(2.) Though this first classing of *vitriols*, with respect to their essence, might seem sufficient, yet it may not be amiss to take some notice of their colours, seeing these first strike the eye: these, exclusive of the white *vitriol*, may be reduced to a green, or a blue, the green martial, the blue venereal; the former is very pale, like a pale emerald, commonly called a grass, or sea-green, and ought not to be confounded with verdegrase, the colour of which is a much higher green, somewhat inclining to a bluish cast, especially when prepared by art from copper and a vegetable acid. The blue resembles a beautiful sapphire and a lasul-stone, as this

this last has, doubtless, its origin from it, as we must necessarily conclude from certain characters and signs it affords. Now as iron and copper, as is before observed, may chance to be united together in a *vitriol*, it may be easily supposed, the colour peculiar to each metal, as green to the iron, or blue to the copper, may be in one case exalted, and in the other lowered; and one become a greener *vitriol*, the other a paler, one combined with something coppery, the other with somewhat of an iron-earth. The white *vitriol* particularly deserves mentioning on this occasion, as it has its denomination absolutely from the colour; yet, by no means, are we to imagine it a species entirely different from the blue and green in its ground-earth (as these are among themselves) seeing it is always coppery, and its white colour is to be derived from something incidental, if not from an aluminous earth, from the nature of its mixtion.

Vitriol might also be classed according to its different forms and figures, and the rather, as there are names to that purpose already extant; *Trichites*, capillary *vitriol*, which often, like wool, hair, and threads, encompasses the mixt or ore-work; *Stalactites*, drop-*vitriol*, in form of icicles; *Cupæ rosa*, as usually settling, in the course of shooting, on the edges of vessels, like so many roses and flowers.

The external, or rather, occasional cause of the origin of *vitriol* affords a further distinction deserving our regard. The internal formal cause of vitrification shall be enquired into below, and is in all *vitriols* so far one and the same, as there is in each sort a metal-earth for its ground or basis, and the highest acid in nature, from what quarter soever

ever it come; nay, both the combination of these two parts, and their proportion, are the same in each: but so far they differ, as this acid salt is derived from different quarters, namely, sometimes from sulphur, which in *pyrites* lies next to the metal; sometimes from the air, being attracted by the desulphurated, nay, repeatedly elixated earth, as by a magnet; sometimes also, without sulphur, it is formed only by the medium of fire, as we experience in that extraordinary body, *calamy*; sometimes a prepared *vitriol-oil* itself comes to be incorporated, in the common manner of solution, with a formal iron.

From all these circumstances to select only the most general; *vitriol* is produced either spontaneously, or by art, and accordingly we have a two-fold sort, a native, and a factitious. But, first, we are to avoid here the being misled by the term *waxing-troughs*, used in the *vitriol-huts*, in which troughs, as the workmen say, the *vitriol waxes*, or grows; since 'tis only a shooting, or crystallisation of a *vitriol* already *waxen* and generated, only still contained in a large quantity of water, which is to be boiled away. Many also imagine grown or native *vitriol*, which *breaks* vein-wise in firm entire rock, such as is the Hungarian sort, to have something extraordinary in it, compared with that usually formed into icicles, or flakes, in old mine-works, though both are originally derived from dissolved *pyrites*, and differing in nothing from that generated at the day.

The several appellations, *vitriolum coctile*, or *vulgare*, *concretum*, *stalactites*, *stillatitium*, *cupæro-sa*, *trichites*, *leucojon*, or rather *lonchoton*, or *lanceatum neophyton*, *diphryges*, *magnesia vitriolata*, &c.

do

do not denote a difference in the thing itself, but only a different method of production or preparation, or something incidental, &c.

Vitriolum stillatitium, stalactites, stalagmites, or drop-vitriol, signify only the figure of this metallic salt, in icicles, jags, and flakes, such as is to be found in mines, like a froze-water, or an ice; also such as usually settles in the pans, trunks, and vessels of the *vitriol-huts*.

Vitriolum concreticum, or condensatum, according to Dioscorides and Galen, is that procured from *vitriolic groove-waters*, by a spontaneous evaporation in the open air. Caneparius, from Dioscorides, alledges the concreted not to be so good as the *drop sort*, but this may be meerly incidental, as one sort may happen to be more saturated, and richer in colour; another, more watery, consequently poorer; but even this last may be heightened in virtue by a more slow evaporation and shooting, as by this means salts come to acquire more of compactness and body.

Vitriolum coctile, or vulgare, boiled or common *vitriol*, is the sort elixated with water from *vitriolic* ores, earths, and stones, particularly from *pyrites*, and procured from the lie by boiling and crystallisation, as is the usual way in the *vitriol-huts*. 'Tis called *vulgare*, as being what is commonly sold, and at an easy rate; also, as it yields another boiled vitriol, which may be called *artificial*, or prepared by art, namely, from a metal, and a *vitriol-acid*, which must needs be right pure and fine, and, on account of its costliness, really uncommon; though in fact this distinction be immaterial, as all saleable *vitriol*, with us, is prepared by elixation

tion and boiling, consequently by art, and a genuine groove-drop-vitriol is somewhat rare.

Neophyton, a virgin vitriol, which, and the *trichites*, are a grown or native sort, either in the *groove*, or at the *day*, from *pyrites* opened by the air, without an actual fire.

Diphryges is a term of considerable ambiguity, yet not without a meaning; this, if not purely *vitriolic*, is yet either mixed therewith, or derived from the matter whence *vitriol* itself generally derives. From the etymon of the word, it should denote something *roasted*, which makes it probable it signifies a burnt or calcined, not a crude mineral, or *pyrites*: or, the term may be derived from Phrygia, and so denote a *pyrites diphryges*, or a *pyrity*, *vitriolic* ore from Phrygia.

Leucon, whence *leucojon* is derived, should, doubtless, denote a white *vitriol*. Mercati and Salmasius hold the term to arise from a passage in Pliny misunderstood, where, with Dioscorides, should be read ΛΟΡΧΩΤΩΝ, *lanceatum*, and not *leucojon*, to denote a *vitriol* shot into needles or lances, consequently of affinity with *trichites*.

There still remains another class of *vitriols*, which though little or nothing relating to their essence, is yet adopted by many, especially druggists, dyers, &c. as the Cyprian, Hungarian, Roman, English, Saltzburg, Admond, Geyer, Goslar *vitriols*. But not to mention, that the veins of *vitriol-ore* may break short, and change, and a new sort of *vitriol* may perhaps be procured, unknown before in that particular place, the dealers in *vitriol* keep up these distinctions only from selfish views.

The nature of the climate seems not to contribute much to the mixtion of this metallic salt, so far as that the one sort need be preferred to the other. The *vitriol-acid*, whether from sulphur, or the air, proves every where one and the same, as all sulphurs are fundamentally the same; the iron and copper, though, in regard to their admixture and working, they may differ according to the different places and times, yet equally lay themselves open to the action of the acid, without communicating any the least foreign admixture. Moreover, it may easily and often happen, that a country shall yield more than one sort of *vitriol* at a time, and how shall these be distinguished by the common name of the country?

Under the appellation *Cyprus vitriol*, there is now a-days sold a blue venereal sort, though, possibly, never from Cyprus. The Roman is properly martial, and somewhat venereal, but, by fining, becomes an *iron-vitriol*. As the times alter, so with them also change the methods of working in a country; nature either refusing to afford any more materials for the purpose, or art finding it more profitable to employ these for other ends; for instance, instead of an *iron-vitriol*, to make a *copper-vitriol*, and *vice versa*, or both at once. The Hungarian fossile, or *atlas-vitriol*, is the only sort, which here, for a certainty, in some circumstances, displays something peculiar, as that among the native sort, it may hitherto be eminently called Hungarian; I say, *in some circumstances*, not indeed in regard to its mixtion, in which it is not singular, but in regard to its origin and *finding*, as *breaking* usually in firm entire rock, whereas other *groove-vitriols* are found in *shafts*, in the sides and roofs of

levels and drifts only, and therefore lying open; I have also said, *biterto*, as the like sort may, some time or other, happen to be found in other parts, when the former will, in course, have its absolute name limited.

Thus long have I detained my reader with a relation of such circumstances as regard *vitriol* only externally, and yet I must add something more, before I proceed to the principal part of this small essay, in order to obviate any doubt and misconception that might still remain; namely, that the term *vitriol* is also employed for other metallic salts, besides those of iron and copper, silver, lead, and quicksilver, also tin and gold; yet the two latter bear somewhat more difficultly the being reduced to salts, which may be, and by many are called, *vitriols*; as *vitriolum lunæ*, *saturni*, &c. But as such *vitriols* are prepared only by means of the salts from nitre, common salt and vinegar, which must be greatly inferior to those in *vitriol* and sulphur; therefore, not by means of the highest salt in nature, or what has reserved to itself the iron and the copper for solution.

Tho' the *vitriol-acid* may seem to enter into some bodies, particularly quicksilver and lead, especially after as due a degree of appropriation as possible, yet not in such measure or proportion, as it is lodged in an iron and copper *vitriol*, which employ a very large quantity of acid; but in a quicksilver or lead calx, thus dissolved, or rather only somewhat corroded, scarce any at all is required, nor is it necessary they should be in such a degree of union, as in a transparent *vitriolic* body, which may be supposed to be more close and tender than such a calca-

calcarious earth, as vitriol-oil reduces the white metals to, and wherein not so much as a saline or *vitriol* form can be exhibited ; nor in such a colour, as that in a quite surprising manner appearing in the unparalleled green and blue *vitriols*, never producible from other metals by their appropriated salts, except from bismuth-ore ; where, under peculiar encheireses, or treatments, not only a genuine *vitriol-green* appeared, as M. Linck and I myself found, but also from my own small experience, a genuine purple and blood-red : nor has hitherto at least, what Caneparius, after the ancients, relates, been sufficiently verified ; namely, *that each metal does in solution shew its own peculiar colour* ; especially if we are willing to ascribe the blue to the silver, and can prove this from a blue silver solution ; though it be certain, this blue colour ever proceeds from some small share of copper in the silver ; it never appearing, if we only run this silver ore over again to its metallic body, and refine it with nitre in the crucible, especially in the case of a coppery lead, and a cold fulmination in the act of cupellation.

I know not, whether to call it an unguarded, or rather an undistinct way of expressing himself, when he pretends, an *iron-vitriol* is distinguishable by a brown-red ; a *copper-vitriol*, by a green ; as here he must certainly mean, not the *vitriols* themselves, but the *vitriol-waters* ; and then indeed an *iron-vitriol-lie* appears of a brown-red ; and yet when pure, it is at first of a beautiful green ; and a *copper-vitriol-lie* seems, but yet is not, really green. But, as iron and copper appropriate to themselves the sulphur-acid, to the exclusion of the other metals, so they not only quit these their native solvents, but also submit to others ; a very remarkable circumstance, and deserving our closest atten-

tion, is, that they not only dissolve in the grand natural acid, but also in aqua-fortis, spirit of salt and vinegar, tho' indeed not with that intimacy of union as happens in the former case, seeing verdigrease, which is prepared from copper and wine-vinegar, or the like vegetable acid, and a *vitriol*, which may be made from it with spirit of salt, are by far not to be compared to a *copper-vitriol* prepared with sulphur. In short, under the appellation *vitriol*, when without any adjunct, specifying its metal, we are never to understand any other than a sort prepared either from iron or copper, or both together.

3. Of the production of *vitriol* from the *pyrites*. This is the last and most important head of enquiry; though indeed, it is not so perplexing as the external descriptions from the names, figures, and kinds of the *vitriol* were, seeing truth is concise and intelligible, and writers having touched but sparingly on this head, it is less confounded by ambiguities and contradictions. We shall for the present drop the white *pyrites*, because it is never known to yield any *vitriol*; and confine our remarks only to the yellowish and yellow sort; which, together with their proper metal-earth also, possess sulphur, by means of the acid salt, of which, the *vitriol*, as a new production, arises from such earth. In the important business of *vitriolisation*, we are particularly to attend to the instruments or means; and as these are two-fold, we have a two-fold *vitriolisation*, or resolution of *pyrites* to consider. The instruments are air and fire; sometimes the one, namely, the first alone; sometimes, and that oftnest, both together; at least the second is not generally successful without the first.

(1.) As to the air, it produces its effects both in the groove and at the day; *pyrites vitriolising* not only

only in veins laid bare, but also in firm, close vein-stone; if only the smallest fissure happen to give entrance to this penetrating, insinuating body; and lastly, in mineral and *pyrites heap-work*, which is either shot in trunks, or otherwise remains lying in the groove. The first may be manifestly observed from a view of such veins laid bare; the second, not only from *vitriolic groove-waters* and *cement-waters*, as they are called, which, according to all circumstances, must have their *vitriol*, not from the contiguous, but from distant and close vein-stones: also from many day-springs, such as several medicinal springs are, which, in places where mines were never worked, carry *vitriol* along with them out of the earth: the last we experience very often; as I have had plenty of such *pyrites* from the Rothe-grube, which I have examined on account of their spontaneous *vitriolisation*.

At the day, or without the groove, they, in various places, become *vitriolic*, yet in some more than in other places; for instance, on that heap, or heap-work of minerals and earth, shot together near the groove, and seldom without *pyrites*; in vaults, cellars, and the like moist places; in rooms and cabinets; nay, on floors under roof or cover, according to the nature of the season, the weather, and the situation of the building. But as the action of the air is here too slow to answer our occasions for *vitriol* speedily enough, the fire is to be called in aid; at least, for the sake of saving time, and on account of many *pyrites*, especially the *copper-pyritæ*, which very slowly yield their contents without its assistance; but the sulphur, in this way of *vitriolisation*, is entirely lost. Now, the fire is here applied in three several ways; either in close vessels and furnaces, wherein the *pyrites* is laid for procuring at the same

time the sulphur, as is the way at the sulphur-huts; or, out of a wind-furnace, whose flame plays on the *pyrites* lodged in an adjoining roasting furnace: or on a roasting-bed, where the *pyrites* may be best thoroughly burnt, or calcined: the first method is that used at Friberg, for the sake of preserving the sulphur.

2. The fire is the next instrument; which, if not entirely sufficient of itself, yet is serviceable for the first opening and preparing the *pyrites*, nay, indispensably necessary for many sorts of *pyrites*, which would not otherwise shoot in the air. It is indeed of itself alone sufficient, nay absolutely needful, for exhibiting *vitriol* from other *vitriolescent* bodies, particularly fossil calamy, from which, without burning, there is no hope of success; and tho' the burnt calamy be never so long exposed to the air, yet it would not, for all that, receive the more *vitriol*; which is something equally peculiar; as is also in this very process and act of burning, the sulphur-production. The burnt, or calcined *pyrites* do also, after burning or roasting, without a previous exposure to the air, yield, by the usual way of elixation, a *vitriol*; but not generally (the reason of which difference I have not yet sufficiently discovered) nor so richly, as when the air has previously for some time thoroughly worked them: but this and a great deal more must be attentively considered.

As (1.) In what the business of *vitriolisation* consists. (2.) What is procured from it.

As to the *vitriolisation* itself, it depends on various circumstances, particularly the following. The air is the principal agent here, and contains

two principles. (1.) An universal moisture, or a rarified water. (2.) A salt fit to incorporate into many bodies, not always in the same manner, but diversified according to the nature of the subject: whence bodies, especially the dry, become not only moist, but also more ponderous: some, particularly the lixivious salts, entirely liqueate, as the *olea per deliquium* manifest; some, and even these, moreover, receive another salt, as the bitter *vitriolated* salts, separating from liquated pot-ash, sufficiently testify. Now, tho' the salt of the air, considered in itself, without at present regarding its saline nature in this or that particular place, be various; or, tho' it may differ according to the difference of the subject, to which it gives or communicates itself, yet this is a thing that cannot sufficiently be explained. However, from the just mentioned *vitriolated* lixivious salt, so much appears certain, that the *vitriol-acid* in such salts, which differs in nothing from that in *vitriol* itself, may exist, if not formally, yet potentially in the air, and be found actually and formally, as such, in these salts; as may incontestably be shewn from the genuine mineral sulphur to be thence exhibited: and thus we have in the air not only what appertains to the exhibition of a salt as such, and to its crystalline transparency, namely the water, as appears from the *vitriol*, efflorescent, or striking out on *pyrites* in bare air, without addition of any actual water; but also, what most properly belongs to the essence of *vitriol*, namely, the *vitriol-acid*; though it be only as an *ingredient* and *immanent instrument* in desulphurated *pyrites*; but in the crude fresh *pyrites*, where the acid lies still plentifully in the sulphur, it acts as a penetrating instrument.

This collective air lays hold on and attacks the *pyrites*, and without it we are never to expect any *vitriol*, not even the spontaneous *vitriolescence* of *pyrites*. For, tho' I have had no opportunity of making any experiments with the air-pump, yet I have observed, that *pyrites*, when kept in a very close glass, especially in a dry and rare air, *vitriolizes* with more difficulty than without the glass: and from this gradual difference it seems, that were it possible entirely to exclude the air, a *pyrites* would with the more difficulty, or not at all, become *vitriolic*. In short, the air is entirely necessary for the purpose, and that according to all and every property thereof, not in its separate but collective nature. For that the water alone is insufficient, appears from the *pyrites* not giving in the least, tho' lying, nay boiled in water never so long; as little effect has the *vitriol-acid* alone, seeing the *pyrites* remains whole, entire, and unchanged in the strongest *vitriol-acid*; nor are both these together sufficient; the affair depending not so much on the matter of the air, as on its motion, its soft and gentle attack, its wavy ambieny and insinuating impression, in order to the accomplishing these destructions, and procuring new productions.

It has been already mentioned of white *pyrites*, that it yields no *vitriol*, tho' its arsenic, of which it principally consists, yield in some measure to the air, as I have mentioned above of the *fly-stone*: it is the yellowish, or universal *sulphur-pyrites* and the *copper-pyrites*, or the yellow copper-ore, that are properly subject to the action of the air; tho' for their improvement and exaltation, yielding slowly, and with some degree of resistance; and with this remark-

remarkable difference, that the yellow give not at all, or with difficulty, at the day, but, in the groove very readily : for, having in various manners endeavoured to vitriolise the copper-pyrites ; or the yellow copper-ore, and for that end exposed it in numerous ways, and in different places, both whole, and beat small, also in pretty large heap-work, both naked and covered, I could never procure any vitriol, though after an exposure of many years ; nevertheless, I would not pronounce the thing impossible, though very difficult : and therefore I would thus distinguish the spontaneous vitriolisation of pyrites, and affirm the yellowish to be subject thereto, both above and under the earth ; the yellow only under, and with the greatest difficulty, above the earth. The reason of this different efficacy of the air depends doubtless on incidental circumstances, into which we are unable, with all our art, to bring the yellow pyrites.

Now, it is a difficult matter to assign either a general or particular reason, why for each sort of pyritce, the vitriolisation happens either slow or quick, or not at all : for, though the copper greatly stands in the way of vitriolisation, yet there are circumstances and examples, wherein this does not always hold good ; as I have had yellowish pyrites that contained no copper, and yet shooting with great difficulty, nay often not at all, into vitriol ; of which we have many instances here at Friburg under the appellation cobald, or a sulphureous, arsenical pyrites. There are two sorts of pyrites, the one from Pretzchendorff, the other from the Ehrne-Schlange ; the latter of which vitriolises, but the former not in the least, and yet they entirely agree in their small copper-yield. But what is most remarkable, there are pyrites, not only agreeing entirely

tirely in yield, namely, having neither copper nor arsenic, no not in the least quantity, but only sulphur and iron along with the unmetallic earth; also one and the same figure, colour, &c. yet one sort; viz. that of Almerode in Hesse, as also the sort from Altsattel by Egra run exceeding quick to this metallic salt; another sort, as that from Boll and Toplitz, very difficultly, nay, if not beat very small, and buried in the earth, not at all. Amidst those contradictory instances, I have sometimes dropped the copper, and assigned as causes, the figure, the colour, and sometimes the texture and the grain of the *pyrites*, sometimes again the arsenic, at other times the unmetallic earth, sometimes the bed, and the adjoining or interspersed minerals, and sometimes one of these circumstances only, sometimes two or three at a time; or rather, as colours and figures are not causes so much as signs only of these causes; from the signs I have endeavoured to come at the things themselves, and from their difference, was obliged to abide by the contents, the mixtion and texture of the *pyrites*.

From the arsenic there accrued a great degree of probability, that as the white *pyrites* does not at all *vitriolise*, its arsenic, according to its greater or less quantity, must at least be the reason, why the yellowish often undergo *vitriolisation*, and the yellow always with difficulty, or not at all; did not that sort, which is without any arsenic, and yet remaining *unvitriolised* as the other, stand in the way: The unmetallic earth, which is two-fold, either flinty or calcarious, afforded no light in the case. From the texture, one *pyrites* appears not only denser and more fine-grained than another, but has also, though no other mixtion-materials, yet another mixtion-guise, as well in proportion as in elaboration

boration and coction ; consequently, the air may work on one sort sooner and easier than on another.

Now, tho' the proportion and manner of connection of the particles of *pyrites* may cause a difference, yet we cannot sufficiently judge of it from their apparent density and rarity ; as I meet with *pyrites*, which, besides their similar nature, appear entirely of an equal grain and cohesion, though not equally subject to *vitriolisation*. From the colour it holds, the yellower the *pyrites*, the less, though not the converse ; and the paler, the more ready it is to give or *vitriolise*.

From the figures, both the external and internal, as the angular, the round, the radiated, the testaceous, &c. there appeared some faint glimmerings of truth. Thus it holds, that the round *pyrites* *vitriolise* with more ease than the angular ; and the radiated, than the testaceous. The reasons I also find in the copper and arsenic, of which, both the round and radiated are usually free.

In a word, I at length discovered the causes that now render easy, then difficult, or quite impede, the business of *vitriolisation* to be various ; one cause taking place in one instance ; another, in another, and often two together, often one only, and often neither of the two : now, these are copper, arsenic, and the texture, and what arises thence, the density ; not to mention the unmetallic earth, concerning the difference of which we may entertain some suspicion, nor the different mixtional proportion.

Copper, certainly, is the greatest obstacle of all to this *vitriolic* resolution, when even in the smallest quantity ;

quantity ; and the higher the *pyrites* rises in this metal, the less it *vitriolises* ; this is owing to the sulphur, which being here set free from the metal-earth, and yet again operating thereon in another manner, is held very fast by the copper, to which it adheres more closely than to iron : then the arsenic opposes together with the copper, not only in the *copper-pyrites*, but also in the *iron-pyrites* without any copper ; instances of the one sort are evident in every *copper-pyrites*-ore, of the other sort in the Halsebrucke arsenical *iron-pyrites*.

Lastly, the business also sometimes depends purely on the texture, closeness, and grain, without any copper and arsenic, though this is the rarest case, as I learn from some periwinkle and muscle *pyrites*, consisting purely of iron and sulphur, yet without ever running to *vitriol*. Often two causes concur, as is ever the case in the yellow *pyrites*, where along with the copper, there certainly lodges arsenic : often, the business turns on one cause only, namely, the arsenic alone, or also purely on the texture alone : often, all the three concur, namely, in the fine-grained and finest sort of *copper*-ores : and, to conclude, we have here a confirmation of the axiom, that *one and the same effect may have very different causes*.

This difference, both in the mixtion and texture of the *pyrites*, manifests itself often in one and the same vein ; where we have *copper*-ore and *iron-pyrites* lying in each other interspersedly ; and again, *pyrites* lying like so many nuts or eggs in a shell, wherein upon breaking it some small veins and eyes of *copper-pyrites* appear. Among the Almerode *pyrites-balls*, commonly called *iron-earth*, and for pure sulphur and iron the properest and best sort,

sort, are found not only radiated and stellate balls, which are at least of a different texture from the globular, but also cubical; which, in regard to their metal-earth, differ remarkably from both the former, and are not without some copper; though the ground and bottom, where they lie intermixed, nay compressed together, be one and the same.

In the territory of Boll, are whole tracts strewed with various sorts of *pyrites*, as the periwinkle, muscle, nut, globe, and *radii* kind; and such *pyrites* generally agree in mixtion, like that sort in, and under the under-turf earth, and of like figures, and neither coppery nor arsenical; and yet I have had instances, though rarely, of *pyrites*, containing some little arsenic and copper, and yet produced in one nest and matrix, near and among the former; a thing not to be wondered at, as such mineral productions are subject to many incidents, which interrupt their growth; nor is it at all surprising to find *pyrites* similarly, and dissimilarly *vitriolise*. The globular resolve soonest and with the greatest ease; the radiated or conical more difficultly, and tho' they should soon enough resolve into *radii* or cones, yet they here remarkably stop short, before they fully change to *vitriol*. The conical consisting of a number of cones or pyramids put together, with their points concurring in the middle, and their bases again projecting into short, either sharp or obtuse, and these again partly in broken angles; and where joined together, they are, doubtless, not so close and firm, as in the remaining parts.

That the air is the genuine and absolutely necessary instrument in *vitriolisation* we have already shewn, and it may be summarily confirmed from this consideration, that *pyrites*, which remain unresolved

resolved in the bowels of the earth, do at the day, or above the earth, remarkably change or vitriolise ; and that without any thing foreign, besides the access of the air, from which, under the earth, they are at least more screened. Now, here it is worth remarking, that in many sorts of *pyrites*, the *punctum saliens* of this new production acts from within the *pyrites* outwards, the *vitriol* not settling from without, but striking out from within ; as sufficiently appears, not only from *pyrites-globes*, which, in their falling to pieces, generally from their middle emit genuine native vitriol, but from other angular pieces of *pyrites*, broke off from veins, and which on the side, where they are thus broke off, ever turn *vitriolic*.

Two questions with respect to the *pyrites-globes* here offer themselves to our consideration, (1.) How the air can break into such close compact bodies.

(2.) Why it does not rather eat into their circumference, and thus operate from without inwards. As to the first, the round *pyrites* in general, or such as *vitriolise* in that manner, are internally, and in their inmost parts, not so close and compact as in their external circumference ; nay, have a small, an almost unobservable cavity ; further, that this sort, as was observed above, consists of a number of cones or pyramids, and not only upon a spontaneous resolution, but upon the application of an external force, whilst still fresh, falls to pieces of such a conical form. Now, as it is at these *radii* or cones, issuing out from the centre, we ever observe the resolution of these cones to happen, they are, doubtless, traces of small tender fissures, or signs of the cohesion not having hitherto become so close, as these cones do not so readily

readily fall to pieces cross-wise, as in the direction of the radii ; and in these fissures, the air insinuates itself to the heart of the pyrites-globe.

This also may serve to account for the resolution of the second question : it is true, the air first acts, or rather falls upon the *pyrites* externally, but it acts most powerfully, when in a proper place, and at undisturbed rest ; both which it finds in the centre of a round *pyrites*, which is in and about the centre, if not quite hollow, yet of a porous texture : whence the closer a *pyrites-body* is, with more difficulty does the air not only force into it, but the less of it can be collected therein. And hence a piece of *pyrites*, which is now no longer a whole, nor thus to vitrify from within outwards, but to be corroded externally by the air, does in the open air and laid naked there, vitrify with difficulty, or not so quickly, as when laid in a heap, and thus lying at rest, and in some measure warm : and thus the innermost recesses of such *pyrites* become impregnated with *vitriol* ; which bursts out by breaking asunder its shell. Nevertheless, when such round *pyrites*, as still lie in the earth, must vitrify, they fall not asunder in such pieces, but remain entire, notwithstanding which they part with their *vitriol*, either by an evaporation, exsiccation, and a reduction to an earth, by an unobserved elixation, though I suspect the former rather than the others ; thus they exhibit themselves internally neither *pyritous* nor *vitrific*, but like a brown, yellowish, rusty iron-stone, or an iron-earth firmly baked together ; as in particular may be seen from periwinkles, and muscles, exhausted of their *pyritous* substance ; which in their shells, still really existing, though generally calcined,

cined, are often, without falling to pieces, entirely shattered and burst as by a force, evidently acting from within outwards ; and this may be judged to be owing to the *vitriolisation*.

The reasons certainly are, the air's neither so briskly entering into, nor so powerfully acting upon them ; in regard they lie, if not in a peculiar and firm narrow case or enclosure, as a stone, which yet is not uncommon, yet covered under the earth, and in some measure only, not entirely, exposed to the access of the air : again, tho' their shells may crack, yet their parts separate not to any distance, as being urged or pressed upon by the adjoining earth and stone ; and though by the act of *vitriolisation*, they may turn to an earth, yet they must hold together, become compact, nay even petrify.

Such periwinkles and muscles stuffed with *pyrites*, or pieces of *pyrites*, of the form of periwinkles and muscles, are found cracked, rusted, and again hardened, at Boll, and the adjoining territory, in great quantities, and in various sorts ; particularly, *chamæ*, *pectunculi*, *cornua ammonis*, &c. but never, so far as my experience has reached, in *lapis lyncis* ; the cavity of which is nevertheless often found filled with *pyrites*, a circumstance deserving peculiar notice ; and I have discovered at the Schloßberg at Toplitz a *terebratula*, entirely rusted and remaining firm ; a thing I never observed before, whatever pains I took in the search.

Further, I besides remarked, that many such sea-shells, exhausted of their *pyrites*, were only externally rusted over ; but upon preparing them both in their entire state and beat small, for *vitriolisation*,

lisation, though in vain, I found them of such close texture, as to render them unfit for it, either externally or internally.

Lastly, I have had instances, where the bodies were thoroughly rusted, yet neither burst, nor fallen to pieces; but then many such shells are not pure *pyrites*, but greatly mixed with other earth, and also stone, particularly, shivery, loamy, and spathy matters; nay, some contain no *pyrites*, but such earths only; and, in that case, neither an expansive force, nor a *vitriolisation*, but only a leisurely rusting, and reduction to earth, are to be expected.

Thus much of fresh *pyrites*; but that the air also works on the desulphurated and thoroughly burnt *pyrites* towards *vitriolisation*, we shall hereafter mention, having first to treat of the other instrument, namely, fire. And here we must premise something on the internal causality, or how the spontaneous *vitriolisation* of *pyrites* happens internally.

Philosophers might readily call it *magnetism*, to denote a mutual action of damps and juices; on the side of the patient, namely, the *pyrites*, consisting in a *receptivity*, and on the side of the agent, or air, in an *influx*. Miners express it by the term *weathering*, and very properly, as they usually call air, *weather*; besides, affirming, that we are by it to understand, not a destruction of the matters of the *pyrites*, but only of its texture or cohesion; least of all are we to imagine it a reduction to its original parts, or a separation, but a new production. The resolution here produced is indeed so far a separation into parts, as the sulphur is absolutely to be set free from its metal earth, but in that very act the

new production happens; and as soon as the sulphur is thus set free, so soon does it lay hold, with its acid or salt, on the loosened metal-earth, and therewith exhibit the *vitriol*.

Hence, in the process of *vitriolisation*, though never so attentively performed, not the least separated sulphur is to be found. Now as little as in this resolution of the *pyrites*, or destruction of its texture, the business is a separation, though this last, in some measure, happeneth; so little is the exhibition of the *vitriol* a separation from *pyrites*, as really, and in truth, to be considered a new production: for, the parts of the *vitriol*, namely, the sulphur-acid and metal-earth, are indeed in the *pyrites*, but not thus combined.

In brief, *vitriol* is as little in the *pyrites*, as brandy and a volatile salt are in the grape and fresh urine; but are all three produced from *pyrites*, must, and urine respectively, by means of *weathering*, fermentation, and corruption; and that not only by a transformation of the particles of the *pyrites*, must, and urine, but also by an actual essential influx of the particles of the air, considered above in their water, earth, and salt, and which here not only pass through, but adhere to the fresh *pyrites* and its particles, i. e. are not so much a *transient*, as an *immanent* instrument; as appears from the several productions and transformations in the three kingdoms.

It seems, however, probable, that air enters not so much by its saline part, as by its universal humidity, into fresh *pyrites*, for the exhibition of *vitriol*. The probability of this hypothesis may be inferred from hence, that there already adheres to such

such *pyrites* much salt, especially in the sulphur, sufficient to dose its metal-earth: and it cannot be shewn, that the least sulphur flies off without producing its effect. We are not, however, to deny the salt in the air its incorporating virtue, as it stands inseparably united with the humidity, tho' its humidity is here still more necessary, for exhibiting a true saline form, such as the *vitriolic* must have, seeing it is in no case procurable without water. And though in spontaneous *vitriolisation* the humidity of the air always manifests itself, yet other water is not to be excluded.

For, first, the former is aided by the latter, as we see upon exposing to rain, or sprinkling with water, the *pyrites*, either beat small, or in its gross state, and laid on large heaps together; *aided*, I say, and not the former replaced by the latter, as *pyrites*, when entirely plunged in water, and thus excluded the access of the air, never turns to *vitriol*: so that notwithstanding the sprinkling with rain and water, the whole businels must chiefly turn on the motion, warmth, power, and influx of the air; and then also, by means of other water, larger and purer crystals are procured, and in a larger quantity. But the moisture of the air alone being employed, the crystals prove small, like grains of sand, nay, often like hairs; and thus, when the *pyrites* falls to pieces and to earth, there is no separating them from the impurities, without either washing them with water, or without elixation and a new crystallisation.

But possibly, from the nature of the grooves, the moisture of the air is not the whole, but the waters, trickling down on all sides, may wash out the tender *vitriol-shoots*, and coming afterwards to

settle a little, or otherwise evaporate, let them fall again, either in icicles, from the roof and sides of levels; whence we must make some distinction between *grown*, or native *vitriol*, as spontaneously produced from *pyrites*, namely, between that sort formed barely by the humidity of the air, without any addition of either day or groove-water, and that other formed by the accession of an actual water. The former we are not to expect in the grooves, and 'tis rare that it is *grown*, though shot on the spot where found: whence appears the great folly of alchemists, in that they would employ for their *great-work* that produced in the grooves by the water of the air alone, a thing quite impossible.

For the *vitriolisation* of *pyrites*, there are, besides the action of the air, other aiding or concurring circumstances requisite, at least when it is to be rendered easier, or to be more speedily dispatched. Those on the side of the *pyrites* itself, though indeed only negative, I have already mentioned, and now come to this, namely, that the *pyrites* must contain little or no arsenic or copper, nor be of too close a texture: to which we may add this conjecture, that the black vein-stone, or rock, usually called *kneiss*, at Friberg, and almost shivery, but much blacker and harder than *shiver*, is, if not a co-operating cause, yet a sign of an easier *vitriolisation*; but as to external circumstances, there are principally three, which facilitate this operation. First, and principally, the *pyrites* is to be laid together in as large a heap as possible, and to lie exposed to the weather and sun, nay, in dry weather to be sprinkled with water, as otherwise it cannot heat or work so well: or, in the small way of proof, the beating small the ore, the choice of a fit place, as a cellar, or the like warm situation, and the laying it in a powdery

powdery heap, are to be called in aid; and these failing, I know not further how to advise, when you would have a *vitriol* without fire, or the addition of any thing extraneous.

As to the other instrument in *vitriolisation*, namely the fire, its relation thereto is somewhat different from that of the humidity of the air. Such *pyrites* as spontaneously yield not to the action of the air, or too difficultly and slowly, or that must previously be worked for sulphur, are first, either roasted, burnt, or desulphurated, and this holds, in respect of the difficulty of *vitriolisation*, not only of the yellow *pyrites*, or our copper-ore, but also often of the yellowish, that is, of many sulphur or iron *pyritæ*. But here occurs a difficulty, namely, that the burnt *pyrites* must generally be thrown on heaps in the open air, though there is also a sort, from which, immediately after burning, nay, tho' still warm, a *vitriol* may be elixated. I made trials with all my *pyrites*, under the different circumstances of being much and little burnt, put warm and cold into water, but often without procuring any *vitriol*.

From the instance of fossile calamy, which, immediately upon burning, nay, whilst still warm, yielded not only a good deal of *vitriol*, but also not a little alum, I imagined the same would succeed equally well, if not better with the *pyrites*, as containing the sulphur, consequently the acid of the sulphur not only so plentifully, but also the metal-earth immediately; whereas in calamy there is little formal sulphur, consequently, little sulphur-acid; but it must first be, by means of the fire, both generated and rendered active. The *pyrites* mixt-work of Geyer, which is properly an iron-stone in-

terspersed with *pyrites*, is a sort, which directly upon burning (for it proves too poor for making sulphur) has been elixated for *vitriol*, yet with me it has not yielded enough; though the reason of such *pyrites* giving *vitriol* without air, barely by means of the fire, be, that the sulphur therein finds a prepared corporal iron, wherein its acid salt may directly lodge, yet the case is certainly different in a pure, firm *pyrites*, the iron-earth of which is not thus prepared. I have, however, procured a little of such *vitriol*, and the small share of *vitriol* from all sorts of *pyrites*, shew the possibility of the thing.

But though I could not succeed in the manner I had been directed at the *vitriol-huts*, yet I find no reason to deny that *vitriol* may be procured from burnt *pyrites*, without a previous exposure to the air, especially when I consider the peculiar experiment of the *vitriol* from calamy: besides, that from the miscarrying in the small way of proof, we cannot question the truth of the large way of working (as, in other respects, the conclusions from proofs in the small to yields in the large way, are often very fallacious) as I have experienced how difficult in general it is to assay *pyrites* for *vitriol*, without employing large heaps for the purpose.

Yet it may be made appear probable, that the air contributes something here, when we consider the nature of fire, as yielding no flame without air, nay, deriving by and from it, together with the fatty, foot-particles, its needful fuel and *pabulum*; and thus the air is at least an indispensable instrument in *vitriolisation*. But be this as it may, such *pyrites* directly elixated upon burning, when, to be further worked for *vitriol*, is to be shot in the air,
and

and there to lie for some time. Upon the whole, by means of the air, a fresh *pyrites vitriolises*, air plays in amidst the burning of the *pyrites*, and, lastly, exerts its efficacy in the heap, when the *pyrites*-earth is become unfit for further impregnation, and thrown on the *flag-heap*, under the name, *caput mortuum*.

Thus the fire is, in the business of *vitriolisation*, to be also considered as an immanent instrument, so far as, in part, the air is not only inseparably contained therein, but is almost the very substance of fire itself; also seeing the fatty, phlogistic particles from wood or coals cannot fail to be communicated, hence an open-roasted resolves better to *vitriol* than a close desulphurated *pyrites*) yet here, fire and air are not to be considered on an equal footing, but fire is also to be considered as a penetrating, opening instrument; particularly as what fits and prepares the *pyrites* for the action of the air. For, not only the sort in general, which must undergo the torture of the fire, is to receive from the air the true matter of the *vitriol*, but also that which immediately upon burning resigns its *vitriol*, is afterwards to be committed to the air, in order to a fuller yield.

Now, all sorts of *pyrites*, whether spontaneously *vitriolising*, or prepared for *vitriolisation* by the action of the fire, will take a long time, nay, a course of years, before nature has thereby worked them dead, or exhausted them of their *vitriol*: but as in the *vitriol-butts* the waiting so long would not defray the charges, besides, that the *vitriol* produced would be apt to be washed away by rain and water, or soak into the earth, and there be lost, were we to wait till the *vitriolisation* was fully finished; it

is therefore usual, within the year and day, to boil out the *vitriol*, according to the plenty of *heat-work*, and in proportion to the demand for the commodity. And should any one, in order to promote the business of *vitriolisation*, take it in his head, that ore, the more it is stamped small and powdered, the more it would lie exposed to the action of its menstruum, from the axiom, that *the more sides a body thus exposes, the sooner it will be resolved*, he would find himself greatly mistaken; as thus, the ore would lie more close together, so as to exclude the action of the air. Yet it depends on practice and experience, to determine whether the often turning what was inside outward, may be of any advantage or no.

It remains to say something of the white *vitriol*, a matter greatly unknown, both in its origination and mixtion: it is white, and not barely so to the eye, as *vitriol* in general usually appears, when in a capillary or woolly state, and consequently fine and tender, or when minutely rubbed, or dried and crumbled by air and heat; but essentially, and in its mixtion, white, as plainly appears from its crystals, be they ever so large and thick. It is true, we have also a bluish sort, but this external blue cast may, by a proper crystallisation, be discharged. Though its origination be utterly unknown to us, yet I cannot omit mentioning what I myself have observed, viz. that the *pyrites* of Pretzschendorff, which is a yellow cubical sort, intermixed with somewhat of a mock-leady matter, and lodged in a black-grey shivery rock, has, after desulphuration, and a long exposure to the air, yielded an actual white *vitriol*, differing in nothing from the Rammelsberg sort, so far as I hitherto find (after purging such from its adhering copper-blue) either in

in colour, taste, or habitude in the fire. And all we learn from the accounts from the Rammelsberg is, that the ores there are also *pyrity* and *mock-leady*.

In the Pretzschendorff sort, it is certain, that besides the *pyrites*, there is also mock-lead, which holds some iron-earth, and a little foaty fly-powder, or arsenic, consequently no other contents than what are in *pyrites*, and therefore the business should seem to turn on the unmetallic earth, which constitutes the greatest part of mock-lead, besides what the external rock may contribute; which though also to be met with in other *pyrites*, yielding no white *vitriol*, yet we are to remember, that new productions, as *vitriols* are, depend not so much on the great variety of matters to make up their mixtion, as on the different proportions of a few, the places of generation, &c.

From the former prejudice generally arises great difficulties in acquiring a competent knowledge of nature, in imagining, first, *mixts* to have taken their rise from such matters as they are found to consist of; the absurdity of which appears from the history of alum, which consists indeed of a calcarious, or if you had rather, a chalky earth, and yet neither nature nor art can produce it from thence: again, in being accustomed, in the operations of nature, to the terms, *extraction*, *separation*, *combination*, &c.

As to the mixtion or nature of the white *vitriol*, so far as my little observation reaches, it may be concluded, its ground-earth is, first, aluminous, then, coppery; the copperiness not only appearing in the common white *vitriol*, as worked from the Rammelsberg ores, by plunging an iron into it, but

but also in the purified, and even the Pretzschendorff sort, which discover themselves by the actual coppery taste, and by its redness after calcination; this colour certainly indicating something metallic, though, from the taste, not an iron.

It might be somewhat difficult to explain why such a white metal-salt should not be procured at our *vitriol-houses*, equally as at the Hartz, did not the business depend on the copperiness of the *pyrites*, which is observed to be more distinguishable there than with us: and as to its unmetallic earth, we have reason enough to affirm, it is not of the same sort with the ground-earth of bitter salts, and arises, if not from common salt, yet from calcareous, spathy stone, from which such middle or *vitriolated* salts indeed may, but a white *vitriol*, though with the addition of a metallic earth, never can be prepared; moreover, we observe nothing spathy among our Pretzschendorff veins: nay, such a *vitriolated* salt may well contain something metallic, as the *arcanum duplicatum*, which, in the burning or distilling for *aqua fortis*, arises from the alcaline salt petre earth, and the *vitriolic acid*; yet so that its fundamental bitterness cannot be concealed, though entirely separable from the metallic impurity; whereas, on the contrary, there is, in the white *vitriol*, neither bitterness to be observed, nor does the metallic taste cease to manifest itself.

Lastly, we are to take notice, that white *vitriol* is never found in our grooves; though, according to Lohneiss, in those at the Rammelsberg, it is met with native in the form of icicles and roses. Thus much we know, that it is procured in the way of a crystallisation, not in large shoots indeed, but like

like a sand only, while urged by a brisk boiling; though from these smaller crystals reducible to larger lumps.

On the head of the origination of white *vitriol*, I cannot omit mentioning a query put to me by an ingenious friend, namely, Whether *zink*, or rather, zinky substances, should here be entirely disregarded? This at least is true, that this surprising body principally shews itself at the Rammelsberg, nay, is no stranger with us at Friberg, under another form indeed; though the greatest artist will find it difficult enough to hit on a method of properly combining it in its separated state with the sulphur-acid, into such a white *vitriol*.

Under the head of *vitriol* from *pyrites*, we must observe the difference of elixations, namely, that many of them, having stood for some weeks, turn mouldy, as happened to myself once from the mixt-work of the Rothe-grube; and again, if I mistake not, from the *terra martis Hassiaca*. Now *pyrites*, as such, exhibits no such appearance, but the adjoining interspersed minerals, and indeed the shivery, loamy, black fatty sort may, though not all, yet a certain sort of them; such in general are those that yield alum; and all of a fatty, bituminous, inflammable nature, or of a muddy origination: though I propose this only as a query, and not as a certain undoubted truth.

There is also incidentally, from the process of *vitriolisation*, alum procured; not from the *pyrites* in its proper mixtion, but from the bituminous matter adhering to the *pyrites*; when its acid chances to lay hold on the metal-earth, it may not, at the same time, leave untouched the black, fatty, adjoining

joining and interspersed mineral, and thence exhibit alum. We purposely omit mentioning why such vitriolic, aluminous *lies* now shoot first to alum, and that *per se*, without a precipitant, as happens in those of Braunsdorff; again, why to *vitriol* first, and then to alum, not easily without a precipitant; and how alum, made *per se*, differs from that made with *addition*, as sometimes of urine, then pot ash, then quick-lime, and sometimes of spirit of urine; and the rather, as we expect a particular dissertation on the subject of alum from professor Baier, at Altorff.

An earth here discovers itself, which is sometimes grey, sometimes yellow; the former called *slime*, the latter, *ochre*: the slime is procured not so much from *pyrites*, as from the earth intermixed and incorporated with it; though whether such earth be ever procurable from the mixtion of the *pyrites* itself, a thing I could never find, deserves examination; the ochre, on the contrary, appearing of a brown-yellowish, also of a rusty cast, and consisting partly of a metallic, sometimes iron, sometimes copper, and partly of an unmetallic earth, is more certainly derived from the *pyrites*, though not immediately, but meditately only, by means of the *vitriol*, to which the *pyrites* must be first reduced. It is found not only near and upon crumbled *mixt-work*, but washed away by the waters, in what is called the *gurs*, or metallic juices, and deserves a peculiar regard; as does also that sulphur-yellow earth, precipitated in boiling for *vitriol*, and burnt to a red colour, yet not to be confounded with the ochre, being not only brighter, but also something more than a pure earth, namely, still considerably *vitriolic* and aluminous.

There

There still remains to be considered a mel-laginous liquor, deserving the more notice, as it has been disregarded, or, at least, not expressly mentioned by any authors, except Geoffroy * and Stahl †. This liquor is such, that (1.) though, by means of the gentlest evaporation, some shoots may be separated from it, yet they are not sufficiently crystalline, and what remains will not shoot further, but only become a dried mass. And (2.) which is the more immediate object of our present attention, that after drying, if again exposed to the air, it becomes smoky, moist, and fluid. Again (3.) when dried spontaneously in a warm air, it ferments like lees, and thus its parts undergo a mutual action among themselves. And here may be considered, what, and how many are those juices, or thick liquors, which contain salts, without resigning them, either to crystallisation, or the other methods of separation; but, for the present, I shall confine myself to the mineral kingdom.

We find arsenic, and what is allied to it, orpiment, &c. which, along with the acid of salt-petre-salt, turns to a very surprising viscous matter: metals might generally be reduced to this form, could the proper medium for each be found out, as the abovementioned friend informs me from his own experience, of gold by means of urine. This business, however, succeeds with iron and copper easier than in any other metals, and in a peculiar manner; especially as they are the two, that, along with the sulphur-acid, assume the surprising beautiful form of *vitriol*.

Copper

* Mem. l'Acad. l'An. 1713. p. 225.

† Bedencken vom Sulphure, p. 285.

Copper furnishes a remarkable experiment to this purpose, upon properly evaporating the green water remaining from a solution of silver precipitated by copper; but iron more clearly, as I have found after employing the greatest degree of care, having more than once observed, that working it with oil of *vitriol* for *vitriol*, there ever remained something oleaginous, that could not be made to shoot, and only became a dried mass: and as I did not over, but rather under dose the iron therewith, I at first began to suspect the purity of my iron; and being well apprized that many sorts of iron, particularly the cast, though I never employed such in this process, nay, other common iron, may contain something extraneous, as common sulphur, which is no constituent part thereof, sometimes lodges therein, I employed the best Steyer-marck steel, as pure an iron as is possibly procurable, and yet even this sort manifested the same thick oleaginous liquor that common iron did, and became dry in the fire, but smoky again in the air.

After the arsenical matters, and the metals, the *vitriolic*, and the like mixtures, are what are procured from *pyrites*, either with or without fire, also from calamy-stone, and the fossile Hungarian *vitriol*; as thus, take *vitriolated pyrites-mixt-work*, as of Braunsdorff, and the Rothe-grube; also *vitriolated Hessian earth*, burnt fossile calamy, Hungarian *vitriol*, without picking out the green pieces; taking the white amongst them as they come to hand, dissolve each in water, filtrate, boil, and evaporate, and set to shoot several times again; then commit what remains, which will prove highly oleaginous, to the softest degree of a spontaneous

neous evaporation, without applying any fire, and thus let it stand for some months, and there will something separate in that time, which proves not crystalline, but crumbly, like hemp-seeds and small peas, and what remains after, proves still thick and oleaginous, as before. Now nothing further happens, but that when the last is not removed with the same care, but the whole left long together to dry away in the mild warmth of a stove, this oleaginous mass, when become of the thickness of butter, heaves and rises like a dough, in its state of fermentation.

As to what M. Geoffroy * has observed in this case, though he divides *vitriol* with more accuracy than M. Lemery, into blue, green, and white, yet he appears not to have had so just a notion of the white sort, which he calls *couverte blanche* †, as he pretends it to be mixed either with some calamy (which it may, in regard to the earth it holds for the generation of alum, and possibly also for the basis of the white *vitriol*) or to consist of an iron earth, and some lead or tin, a prejudice he was probably led into from the white colour of the *vitriol*.

Now the oleaginous smearable matter remaining after the shooting of the *vitriol*, and which he calls the *mother-water*, he procured not only from fresh *vitriol*, but also from the sort he dried to whiteness, and likewise from what he had treated in the fire, to yellowness, for obtaining the volatile spirit of *vitriol*. He then observes, that from fresh *vitriol*, upon the first re-solution and crystallisation, a grey muddy earth had settled to the bottom of the glass; a thing

* Hist. de l'Acad. l'An. 1707. p. 237.

† Ib. l'An. 1713, p. 48. & Mem. p. 225.

a thing I never remarked, though I have committed *vitriol-lies* to as long a degree of evaporation and separation, as ever M. Geoffroy did.

It is true, I observed something of a sulphur-yellow, but never such a grey muddy matter from pure *vitriol*; whence I conclude, his *vitriol* was impure, or otherwise fullied. He again observed, that after standing in the fire 'till gilded, it yielded a larger quantity of it, than if dried to whiteness only, and still more, than if taken just fresh for the separation of this *mother-lie*. Again, that this *vitriol*, once used, yields the same a second, a third, and a fourth time, nay, repeatedly, or 'till the whole mass of *vitriol* employed be thus consumed and spent. Further, that upon each repetition he procured a yellow powder: that the *mother-lie* grows hot with the acid of *vitriol*, ferments remarkably with the acid of nitre, with oil of white tartar, at first only softly, but soon after also in a violent degree: that after drying and ignition in a brisk fire, it again turns smeary and fluid in the air.

Now, in order to account for this, M. Geoffroy affirms first, that it must be allowed to be, in some degree, alcaline, as it appears ropy, like a run lixivious salt, and violently effervesces and heats with the acid of nitre, like any other alcali: also, that this salt is only derived from the acid of *vitriol*: and then, that being not only in taste, though without any remarkable acidity and sharpness, astringent, but likewise fermenting and heating with alcali's, there may be a proper vitriolic matter still contained therein, separable by accurate repeated shootings; or if still withheld, may, in time, spontaneously bewray itself in the yeſt thrown up

up in the course of the fermentation: and lastly, in regard to the causality of this alkaline *vitriol*-liquor, he explains himself in such a manner, as would make one imagine a transmutation of the *vitriol-acid*; but he does not say, at least not distinctly enough, whence the matter is derived, which we must doubtless suppose, for the exhibition of a dry lixivious, and the incorporation of the acid salt.

That the acid salt of *vitriol* should become, I will not say alcalised, yet changed so as to lose its nature and essence, appears, among other instances, from distilling oil of *vitriol* upon quicklime, when there arises a mass that entirely turns moist in the air: but even hence we see there is something which destroys not only the mixtion of the acid *vitriol-salt*, but must also give it a body. In short, this change cannot happen without some concurring cause, and what is here procured cannot properly be held for a changed *vitriol-salt*, but for a third thing, something which must take its rise from the two other, namely, the acid salt, and an earth.

To give my own thoughts upon this subject, we are to observe, first, that such soluble, vitriolic remainder shews itself on three different occasions; (1.) upon the lixiviation and elaboration of the *vitriol* from its crude ore; (2.) upon the re-solution and crystallisation of a purified *vitriol*, already separated from its ore; (3.) in the usual way of preparing *vitriol* with iron and oil of *vitriol*.

The second is what gave occasion to M. Geoffroy's remarks, but which I must pass over. The first, of which he makes no mention, is properly within my province, as relating to the *vitriolisation*, consequently the history of the *pyrites*. The third

I have only employed as a kind of auxiliary means towards the discovery of the cause of this surprising vitriolic production.

And here, to abide by the first, I have found,

(1.) That all crude *vitriol-boilings* leave behind a fatty, thick, oleaginous lie, be the *pyrites* prepared either with or without fire, *vitriolised* above or under ground, and the vitriol soaked in the earth and stone, or caked together in the open air.

(2.) It ferments with alcali salts, and lets fall a bright brown earth, but never with acids.

(3.) Upon setting it by for some months out of the reach of the fire, something shoots from it like small crumbly grains, plumose and aluminous, as was already observed.

(4.) But, if the whole be left together to evaporate, without separating this matter, it turns thick like a resin, and at last becomes a grey whitish mass.

(5.) In the course of the evaporation, which is performed in the soft heat of a stove, I once observed it heave and rise, and the glass, scarce a third full, to become quite filled therewith.

(6.) This grey mass taken directly, whilst hardly cold, ferments readily with alcali, but in no sort with acid.

(7.) Even upon exposure in the air, it turns moist and smeary, exhibiting the same phenomena with acid and alcali as before.

(8.) Di-

(8.) Distilled in an open fire, it yields an acid spirit, and leaves behind a bright, brown-red earth.

(9.) This earth still proves moist in the air, yet more or less, according as it is more or less burnt.

(10.) Even after ignition in a crucible, it still attracts, though in a very small proportion, the moisture of the air.

(11.) The last separated aluminous matter, n° 3. distilled apart, gives also an acid water, and leaves behind a spongy, grey, and here and there reddish spotted cake, which equally turns moist and smeary in the air, as n° 7.

(12.) What remains behind of n° 3. proves neither thicker, nor more oleaginous than before.

(13.) What remains from the *vitriol*, prepared from iron and oil of *vitriol*, and dried, turns also smeary, flows in the air, and ferments with alcali, but by no means with acid.

Now, from these proofs thus much at least appears; that this oleaginous residue, from *vitriol*, does, after exsiccation and ignition, become smeary, nay, sometimes flows in the air; but whether it will ferment with acids, and thus exhibit an alcaline nature, is a different question; not that I would entertain any doubt about M. Geoffroy's experiment, as being made and repeated expressly, and not a thing purely incidental, though it is what I could never observe: but that it may be exceedingly possible, appears, as was above said, from its spontaneous

neous fuming and frothing, and turning, after excitation, smeary in the air, like an alcali.

Whatever be in that, thus much we know, that this vitriolic residue consists of two parts, namely, the *vitriol-acid*, and an earth, as appears by an entire expulsion of the acid, by means of a thorough glow; whence it seems that these two parts were but slightly combined, consequently, that they cannot constitute a genuine alcali, as from such the *vitriol-acid* can never be expelled *per se*: but again, there must also be an earth, without which no excitation can be procured; and he who considers, or rather, manually treats salts, with respect to their productions, transmutations, origination from, and reduction to earth again, will find such phænomena exhibited from a *vitriol-acid*, and an earth; though he may be unable to assign the formality, or remote causes, which generally lie concealed from us in other instances.

That this earth is from iron seems probable; for to what Homberg † has remarked of an iron fattiness exhibited by means of a burning-glass, and what others credibly relate, of a quicksilver from iron, Dr. Rothe has added some weight, in his dissertation on metallic salts: not that I would ascribe any thing peculiar to iron before other metals, as it is a sort having only proximately its origin from a crude unmetallic earth, and with which, as one of the coarsest, earthly metals, many things may chance to be incorporated.

A brown-red earth, called *caput mortuum*, remains behind from *vitriol-lies*; but then only to be so denominated, when no longer containing any thing living and pungent, i. e. saline and rapid;

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† Mem. l'an. 1710, p. 303.

consequently, is a thing dead and effete, no more to be boiled for vitriol, but thrown away as useless.

Two queries still remain behind, viz. (1.) Whether a *vitriol* may not also be arsenical, or partake of arsenic: The reason of the query is, that *pyrites* are not without arsenic.

(2.) How the case holds with the *vitriol* and its *pyrites*, also with the alcaline earth in medicinal springs.

A certain spring, which I highly esteem, but leave nameless, to prevent the entertaining any prejudice against, or disadvantageous opinion about it, gives occasion to my first query. That it is arsenical is plain, not only from the white sublimate procured from it, but also from the actual arsenical odour, it strikes the nose withal. Yet, neither on this nor the other circumstance, is any great stress to be laid at all times, especially when the arsenic is in so very small a quantity, as is the case here, that it cannot be sufficiently examined; for, phosphorus also gives forth an arsenical odour, which I have also smelted from a lead-process, where nothing arsenical, but salts only were employed; and salts, such as are in the nameless water, may, in their mixed crude state, volatilise a little, though not, in their separated state, or not so easily without peculiar additions, appropriations, &c.

As *pyrites* generally contains arsenic, this arsenic may lodge in that sort from which the water may receive its mineral constituent portion. The possibility of the thing appears from the Friburg

Schlacken-bad, where some arsenic, by means of sulphur and *vitriol*, insinuates itself into the water, which notwithstanding, has as good effects, and performs as good cures as any other medicinal water. Not that we are to imagine such waters to hold great quantities of arsenic; it sometimes scarce amounting to grains, nay, not to one eighth of a grain in several pounds of water, as I have found in the *Schlacken-bad*.

And though a water should happen to hold a greater quantity, if not to a very extraordinary degree, it should not therefore be considered as noxious and poisonous, but its innocence, nay, usefulness, ought to be judged of by the effects, and not by pre-conceived speculations. It is, however, true, that of all the *vitriols* I have ever examined, I found no one sort arsenical, though such a thing might be surmised from some *groove-vitriols*, in consideration of the arsenical admixture in their *pyrites*.

Lastly, to mention something on the head of *acidulæ* and *thermæ*: these certainly, in regard to their *vitriol*, sulphur, iron, copper, arsenic, also their alum, take their rise only from *pyrites*; the *vitriolisation* of which loosens these parts, and fits them to incorporate with the intercurrent waters, and to render them mineral.

The other contents, either a pure, or a *vitriolated* lixivious salt, though the last becomes such by evaporation only, are by no means produced, as none such can be procured from *pyrites*. And here principally we have two queries to make.

(1.) How

(1.) How it happens that most of these waters contain the above-mentioned minerals in a very small quantity.

(2.) How two such opposite matters, as a lixivious salt and a *vitriol* can consist together, without laying hold on each other.

As to the first, we have often water in the grooves, remarkably *vitriolic*; but, so far as my knowledge of the springs in Germany, England, France, Hungary, &c. reaches, no such thing can be affirmed of those at the day, seeing these discover only the least *vitriol*, or other mineral possible: which, in some measure, we may account for from such waters taking their rise nearer the day, when the more day-water coming to mix with them, they thus become weakened and diluted.

But then, that mineral springs should remain of one constant yield, and become neither richer in hot, dry, summer-weather, nor remarkably smaller or poorer in the moistest harvests and springs, we must ascribe to such waters having a distant, deep, and not a near origin, not only in respect of their mineral particles, but also their universal watriness; likewise, to such *pyritæ* as *vitriolise* sparingly and leisurely: not to insist on their great plenty; as there are springs that have continued running for a long course of years; which shews the stock they are derived from to be inexhaustible.

Hence we exclude all *pyritæ*, vitriolising so easily, so richly and so quickly, as the round in general

neral do, which lie directly under the surface of the earth, as those of Altsattel, Almerode, &c. For the same reason also we deny the *copper-pyrites*, or copper-ores, as these always supply a *vitriol*, if not entirely, yet in part coppery; consequently, a something not to be met with in our medicinal waters.

We must therefore have recourse to *pyrites*, *breaking* in fissures and veins, and not coppery; and affecting, if not the cubical, yet the angular figure; which are not, or least of all, coppery, yet vitriolising difficultly and sparingly.

As to the other query; namely, how such opposite matters, without being thrown up together, and thus continuing in their mixtion and nature, can remain separate and undestroyed. This is not the only instance we have in nature, being furnished with a similar one in the above *vitriolic* residue, wherein an alcaline and acid salt lie contiguous, and remain at rest, though at length they are embodied, and discover themselves by a fermentation or heaving: nor again, are we at a loss to account for it; for the highest mineral acid never remains in a separated state, but always united to something; as here in medicinal waters, either to an alcaline or metallic earth. Now, when such waters come to ferment and heave with acid salts, we must certainly conclude, the alcali therein is neither combined with, nor subdued by the acid; and though, by means of evaporation, a yellow earth falls down, such must arise from the destruction of the *vitriol*; and from the falling down of the earth, we may conclude to the presence of the acid, as being separated from this earth, and only unobservedly insinuated into the adjacent alcali;

alcali; and the more so, the more it is set free from its vitriol-mixtion by continuing the evaporation.

That these do no sooner lay hold of each other, must be owing not only to their dispersion, but also to the over-proportion of water. For, as soon as only a little of the water is evaporated, so soon do these antagonists fall upon each other, after having hitherto remained so long in peace. Now, as the acid sooner, and more firmly unites with alcali than with metallic earths, so here the acid lets go the metal under the form of a yellow earth, and combines with the alcali.

Here I mean only such waters, where, along with the *vitriol*, the alcali manifestly lodges, as is generally the case in medicinal springs: but should you meet with *vitriolic* waters, affording no suspicion of an alcali, nor exhibiting any; and yet the *vitriol*, after a degree of evaporation, coming to be destroyed, as shall sufficiently appear by the precipitating yellow earth, there must be other reasons of this appearance, or your experiment has not been accurately gone about.

If no formal alcali can be exhibited, it must then be common salt that presents its alcali; whereby *vitriolic* waters turn easily muddy and ochry; again, if no common salt, it must be something earthy, without participating of which a ground-water seldom is found, to which, if the *vitriol acid* does not fasten, yet it may become contiguous, so as to let fall its metallic earth, which does not hold very firm thereto: and if there is no precipitation, yet waters generally, by long boiling, leave behind an unctuous, fatty, brownish liquor,

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tasting bitterish, smelling lixivious, and though not formally alcaline, nor yet visibly fermenting with acids, but approaching thereto: this appears at least from all our Up-land, and probably too, holds good of the Low-land waters, provided other gross, earthy, and saline parts intermixed, stand not in the way of a proper separation and exhibition. Moreover, there is no great difficulty to resolve a body of such feeble texture as *vitriol* is (which gives in the very air) especially that little of it generally in waters.

Further, concerning the alcaline salts in mineral waters, though it be difficult to assign their origin, yet there are several springs, from which they may be procured in a quite easy manner. For, not to mention common salt, as being plentifully to be met with in the earth, and which (a thing well to be observed) is the only matter, from which, with the addition of the acid of sulphur or *vitriol*, a bitter salt, like that from *acidula*, is procurable by art; especially as such bitter, or spring salt is to be met with in all *soles* or brines, as Professor Lehman, a person much conversant in salts, has discovered: nor to insist on lime-stone and gypsum-stone, nor what is allied thereto, spath, nor cat-silver, Muscovy-glass, *selenites*, *glimmer*, and the like, as being all of a spathy, and spath of a calcareous nature, and all, in particular spath, which lies by *pyrites*, of an alcaline nature, and with acid capable of putting on the appearance of a salt, as we learn from the white *tophus* in the Prudel spring at the Carlsbad; I shall only propose, by way of query, another sort of earth or stone, which the alcali in question may, among other things, be ascribed to, especially when we come to consider the business of the conversion of earths into salts,

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and of salts into earths, and of these last among themselves ; namely, that fatty, black, grey, shivery, unctuous earth and stone, eminently *breaking*, by *pyrites*, and from which alum is usually produced, and thus probably of a luty, slimy original.

Amidst certain circumstances, especially as soon as such earth, procured from such stone, is laid hold on by the vitriol-acid ; or rather, as soon as the acid in this stone itself comes to work ; or more properly still, as soon as this stone comes to act upon itself (whereby not only the vitriol-acid by the attraction of the air, but also the aluminous earth is formally made ; in short, the alum produced not only in its whole, but its parts) there indeed such stone cannot arrive to the alcaline earth we are here in quest of, as in this production in general, not proving saline, but stubborn, calcareous, or highly cretaceous. And yet, what is this more than a conversion ? But, when the vitriol-acid comes not thus in play, as we may learn from the alcali lying quite naked and unsaturated in *acidule*, and thence coming to ferment with acids, there indeed the circumstances, consequently the difference cannot minutely be made out, but must be charged to the score of the difference of elaboration, and other incidental circumstances : so also such stone exhibits not its habitude to acid, but something, namely, the alcali, according to aptitude rather peculiar than incidental to it. In short, let this stone be properly burnt, and the alcali, tho' in a very small quantity, will become manifest not only from its habitude to acid, but also from the actual exhibition of a bitter salt.

But

But here it will be objected (1.) that such waters also hold an acid, and thus the alcali lies not naked therein; (2.) that we must here mean not an alcali prepared by fire, but a natural sort; (3.) that even in this formation of alum, an acid and alcali come together, as when one conveys an acid on such burnt stone, and yet *there* no bitter salt, *here* no alum is produced. As to the first, it is true, the alcali is not combined with, but stands apart from the acid, which is still joined with the metallic earth, as was said.. As to the second, the axiom holds good, that we cannot form any just conclusions from what happens above the earth, or by means of art, to what happens spontaneously in the bowels of the earth: nor, conversely, that what happens not above the earth, or by art, may not happen naturally under the earth, in certain circumstances, through length of time. Again, here serves the experience or observation of a calcarious earth, or stone, being not only corroded by, but capable of being incorporated with bare water, which shall still remain clear and transparent: and as to the third, in the instance objected, the acid is not first produced or formed, but derived, as already formed, from elsewhere; whereas, in the other case, it must become such in the act of *alumination*, so far, namely, as it arises, without *pyrites*, from the pure stone abovementioned.

C H A P. XIII.

Containing the several U S E S of the PYRITES;
and, 1. with respect to the making of SULPHUR.

P Y R I T E S is worked for sulphur, either expressly or incidentally; in the one case it is *driven*, or forced off in pipes or retorts, in the other procured in the course of roasting the ores: by the former method, both here, at Friberg, and at other places; by the latter, particularly at the Hartz, as follows, according to Lohneiss*.

‘ They take, says he, of the small ore, that is, ‘ both of the small sweep from the ore of the ‘ grooves, and from the vitriol works or lies, call- ‘ ed also *vitriol-smal l* and *kernel* †, and shoot it on ‘ a heap one foot high by twenty broad and long; ‘ on this there is wood laid close together, the ‘ whole breadth of the small ore, and piled three ‘ foot high; then on this wood the ore is *shot in* ‘ greater or smaller pieces, as it comes to hand; ‘ and, to one roast, are taken between 1500 and ‘ 1600 measures, each weighing 5 and 1 half cent- ‘ ners: the roasts are made square, and raised nine ‘ foot high, and covered all over with moistened ‘ small-ore for a large *band thick*, and struck close ‘ and firm. From the middle of the roast is ‘ reared a brand of dry wood, reaching quite thro’ ‘ the ore, and over-topping the roast. The roast
‘ being

* Bericht vom Bergwerk, p. 80.

† Kernel is the best or richest small ore.

‘ being compleated, the smelters take from the huts a ladle-full of hot flags, pour them in on the brand, set upright in the roast : and the wood generally burning down in a night’s time, the ore, if left to itself, will continue burning for eight, nine, or ten weeks. There is much *sulphur* procured at present from the Rammelsberg ores, of which the old workers knew little or nothing, and much more may still be obtained, by proper management.

‘ For instance, thus the covers of the roasts being, as is said, burnt down, they become soft by the great degree of heat ; and then, with a piece of timber, they are stuck full of round holes, for the *sulphur*, which retires into them, to be laded out with iron ladles. The *vitriol-small* and *kernel* here employed, should seem to promote the caking of the covers, to prevent the more easy evaporation of the sulphur.’

Instead of the above holes, they now make certain sinkings, or pits, about two feet in diameter, by a foot and a half deep, which are struck firm with *vitriol-small*, and stand asunder the length of one diameter. Now, the roast burning from below upwards, the *sulphur* retires into these pits, out of which it is laded with iron ladles into moistened tubs. It would require no fining, did not some of the *vitriol-small* drop into it in the lading, and thus taint the *sulphur*. The first fining is performed in iron coppers, wherein the *sulphur* melts ; and after the coarse, impure parts are sunk to the bottom, it is cast in moulds ; what thus remains behind, is in the second fining treated like the crude *sulphur*.

The method of working sulphur expressly at Freiberg, M. Rosssler * describes thus: ‘ For the purpose, there must be a driving and a fining furnace, both to be properly proportioned. The sulphur, or driving furnace, is built in length, in such a manner, as between the two front, or head walls, to admit of either eleven, thirteen, or fifteen pipes, to reach across from wall to wall ; also lower, there are either six, seven, or eight pipes, placed at a height ; over the spaces between these, another row of five, six, or seven pipes, also at a height, so that each pipe may come to be within the reach of the fire, and become ignited. The width of this furnace must be determined by the length of the pipes. Over the pipes, from one head or front wall to the other, is turned or cast a flat arch of tiles, with a number of holes left, of the size of a small arm, for discharging the smoke of the wood. The pipes are made of good stuff or clay, and two and a half inches thick, and nine inches wide at the mouth, which is flat in the under, and somewhat round in the upper part, and to be so made, that a clay plate may be shoved down over it, and again removed occasionally ; from the mouth they run tapering off to the other end, where the sulphur runs out, leaving an aperture only of an inch. Behind, where the sulphur runs out, there is left on the wall a settle, whereon the lead-pans may stand to receive the snouts of the lower pipes ; and for each upper pipe a small wall is raised for their pans. The pans are square, with a flat half cover, reaching half way : some cold water is put into the pans, for the sulphur to run into and be quenched in. The furnace is heated with billet-wood laid on a grate, through which the coals may fall down. You must be well acquainted

* Berg-bauspiegel. 1. iv. cap. 16. p. 155.

‘ quainted with the nature of your *pyrites*, as all
‘ of them cannot equally with profit be worked for
‘ *sulphur*; also know, what quantity may be lodg-
‘ ed in at once and burnt in eight hours. When
‘ eleven pipes are employed, for the week about
‘ 126 centners of *pyrites* must be worked, eighteen
‘ centners for the twenty-four hours, and six cent-
‘ ners worked each time for eight hours. From
‘ *pyrites* of an ordinary yield, there may in a week
‘ about five and a half centners of fined *sulphur* be
‘ procured, the centner of *pyrites* reckoned at four
‘ and 1 half pounds. The pipes, as was said, must
‘ be made of good stuff, and not overcharged, as
‘ the *pyrites* is apt to swell and heave, which
‘ might endanger the pipes. Also the arch, next
‘ over the upper pipes, to be left open, there be-
‘ ing then a greater degree of heat, and a better
‘ drift of *sulphur* procured.

‘ The crude *sulphur*, when there is a quantity of
‘ it together, is done out of the lead pans into ob-
‘ long fining pots of iron, which are lodged in the
‘ fining-furnace, and fitted with clay-helms and
‘ earthen receivers; and thus the *sulphur* driven
‘ or forced off, and then from the receivers tapped
‘ off into other pots, wherein it is suffered to cool
‘ a little; after which it is cast in moulds, in long
‘ rolls, and packed up in vessels: in the fining
‘ there is a fifth part waste. In the fining-pots, af-
‘ ter forcing off the *sulphur*, there remains behind
‘ the drofs, called *sulphur-flags*; which, whilst still
‘ hot, are to be removed with an iron ladle. The
‘ *pyrites* thus worked is thrown aside, and some of
‘ it used as *additions* in the operation of *crude-*
‘ *smelting*, and the rest of it boiled for vitriol; but
‘ what is designed for this last, must lie for thir-
‘ teen weeks in the open air before it can be used.’

The method of working for *sulphur* at Dylta in the Province of Nericia in Sweden, we shall next describe. This is one of the greatest works for *sulphur* in the whole kingdom; and here they also boil for vitriol and alum. The matters, from which all these things are drawn and prepared, are a yellow-greenish, dark-shining, ponderous *pyrites*, not breaking there in the high-land, nor at great depths, but beneath the under-turf earth in low-lands or levels, also in the firm rock or stone; and lies in layers or *strata*, that is like a *flat-work*, at between three and four fathom under a cover of common stone, about a finger thick. When they would work upon it, they clear away all to the ore, on which they lay wood to burn, and on the heated ore pour cold water, which makes it the easier to work; after which they break it in pieces, and convey it on a heap together: and as all this is done in the open air, they can only work at it in the spring and summer seasons; for, in winter and autumn, the groove, which is very wide, and stands uncovered, is generally half full of snow and rain. In the working seasons, twenty large iron pots or retorts, weighing between eighteen and twenty-one centners, are filled only a third, as the *pyrites* greatly heaves by the heat; and these pots are placed in a vaulted furnace, in manner that the bottom of the one shall touch on the neck of the other; and, on both sides of the furnace, are ten apertures, five in the upper, and as many in the under row. Then the iron-receivers are fitted on to the pots, and well secured with luting; and fire being made under the pots, the coarse *sulphur* is forced off into the iron-receivers at the rate of four and a half centners in twenty-four hours, according as the *pyrites* happens to be richer or poorer in *sulphur*; whilst some of

the finest parts, exuding through the pores of the iron, and coagulated by the cold air, yields pure *drop-sulphur*. Whence, in summer-weather, every morning about sun-rising, in harvest and winter every evening, the *sulphur* is removed out of the receivers, and the desulphurated *pyrites* out of the pots, and replaced with fresh as before. The *sulphur* is again melted in an immured pot over a gentle fire, in order to its fining, and then cast in the usual moulds. The desulphurated *pyrites* is laid on heaps in the open air, and the following year, according as it happens to be moistened by rain, begins to take fire, and burn so long, till all the *sulphur*, still remaining therein, be quite consumed. Thus far the more antient workers went; but the new, discovering that the desulphurated heap was impregnated with vitriol, and the more so, the longer it lay exposed, conveyed this refuse into large vessels, poured water thereon, and made a lie. But at present, it is put into lead-pans, and boiled for some hours with water: from the former, this lie is conveyed into other lead-pans therein to boil, till the vitriol-master sees it is fit to shoot, who must have the dexterity of attempering it by pouring in some of the first lie. Now, after the lie is boiled, or soaked to a proper degree of thickness, the fire is lowered, and the lie poured into coolers, there to stand, till the vitriol shoots to crystals on the birchen twigs put therein. What remains unshot, is again boiled along with new desulphurated and vitriolated *pyrites* in the second pans, and further brought to crystallisation. The number of huts is two, of pans to each hut four; always two for crude lie, and two for good lie; each weighing thirty centners, and standing on large iron grates, that they may come by no damage: and yet the pans for the good lie last not above five or six years, and those for

for the crude, not above three; in regard the earth burnt-to adheres so firm to the lead, that, if never scraped off, the lead must needs melt. Now this lie, after all the vitriol is shot and removed, the alum-boiler takes to his hut, pumps a water thereon holding metallic particles, and adds a lie of wood-ashes, whereby the green vitriolic colour is discharged, and the white colour of alum procured; it is boiled over again for twenty-four hours in lead-pans, and afterwards suffered to cool and shoot; then the alum is fined and done: the remaining lie is put into a large vessel, and after standing for eight days, it concretes as a crystal into the figure of the vessels, and afterwards is broke in pieces, and is saleable, or fit for the market. There pass at least between five and six weeks, before a vessel which holds about eighteen centners, can be filled with alum; and when boiled in harvest or wet weather, or left too long in the vessel, it generally turns of a somewhat greenish cast *.

II. To the boiling for VITRIOL.

At the sulphur-works there is generally a *vitriol-work* too, as the burnt *pyrites* is well fitted for that purpose; though there is also a *vitriol* boiled from a *pyrites*, from which never any sulphur was made. Such a work requires a lead-pan seven feet long, six feet wide, and about two feet deep, weighing between twenty-four and twenty-six centners; then three lie-trunks, eleven feet square, and two feet high. From the burnt *sulphur-pyrites*, which give or resolve in twelve weeks time, there are ninety-six centners run into one trunk, and there lixiviated with water, and the lixiviated water collected in one

Z 2 vessel,

* Leopoldi relatio historica de itinere suo suecico. An. 1707.
ad Dr. Woodwardum, p. 84. seq.

vessel, there to fine: then this lie is poured into the lead-pans, and boiled, and fresh lie always gradually poured in, that the pan may still remain full; according as the lie is strong or small, more or less *vitriol* is procured; generally, a pan amounts to between six and seven centners. In the boiling, care is to be had, that no sort of tallow, oil, butter, or grease, come nigh it, otherwise the *sod* or boiling is marred; and when it begins to have a skin, it is enough, and then the *sod* is let out into a large trough, wherein it may also fine; from this it is shared out into shooting-troughs, one of which generally yields one half centner of *vitriol*. In the shooting-troughs pieces of wood are suspended, whereon the *vitriol* may hang and shoot; the remaining *sod*, from which the *vitriol* is shot, is poured again into the pan to a fresh lie. At times, fresh roasts must be used for it, and that every week, for the lixiviated *pyrites* to be again burnt, and again lixiviated; they are so often used, 'till at last they must be sifted, to separate the small parts, which are of no more service, and though fluxile in smelting, yet give no *stone* or *regulus*. Sometimes the *vitriol* refuses to shoot duly, and here the masters use a peculiar piece of skill, which they will not readily disclose. In other places, where no sulphur is made, they use new and old *pyrites*, of which they make seven roasts, each at forty six centners; employ four large lie-trunks, and procure from the seven roasts in a week about forty centners of *vitriol*, for which there must be every week employed above one hundred centners of new *pyrites* *.

III. To

* Rosler's Berg-bau-spiegel, Lib. VI. c. 17. p. 156. seq.
Lokneiss, p. 329.

III. To the making of ARSENIC.

Arsenic is made partly from a peculiar *pyrites*, or cobald, partly from a sort, amongst which tin-stone is found, partly from the small-cobald, partly also from the gold and silver holding *mispickel*, or white *pyrites*; and all these cobalds or *pyrites* must previously be parted from the barren minerals, by stamping and washing, and made into a pure *sludge*, from which afterwards, by means of roasting and burning, the *arsenic* is forced out in the fume, and catched. Formerly, the furnace had one small aperture, by which the fire was kept up, and the *sludge* stirred; was internally about eight feet wide, and something longer, and two feet high, like an oven, with an arch over it, and on that a long horizontal passage, or funnel, of masonry, eighty-eight feet long, of the height of a man, and three feet wide, called the *meal funnel*; on the end of it was erected a pipe for discharging the smoke of the wood and the *arsenic* fume; at proper distances in the funnel were windows or apertures a foot square, which were set open at taking out the *meal*. Now, when a *roast-work*, or quantity of *sludge*, was burnt in the furnace, after being first well stirred, the *arsenic* or fume being retired into the horizontal funnel, fell, at length, like a meal, to the bottom, and, in part, adhered thereto. Upon the furnace's cooling a little, the *sludge* was drawn, and replaced with other, which was roasted and burnt so long and so much, 'till all its wildness was forced out, as was done to the first: and thus they proceeded, 'till they were to remove the *meal* from the long funnel, which was done by persons whose faces were bound up, especially the nose and mouth, and who had before swallowed some bacon: but at

present they use a furnace, with a cavity and two mouths, and divided in two parts, and having over the smoke-vent such another passage or funnel, as above described, though not all of masonry, but partly of wood, nor quite straight, but with three or four crooks or windings, against which the arsenic-fume may strike, and the meal settle. The meal, in order to be fitted for market, must be sublimed like a cinnabar, which is performed in a hut, somewhat high and open above, like a roast-house, wherein is built an oblong, vaulted furnace, about three feet high from the earth, and so long, that three plate-hoods, the width of each asunder, may stand thereon. Above, in the vault of the furnace, three round holes are left with each a dish of cast-iron, and on each dish an iron hood of plate, below so large and round as to fit the dishes, and tapering to an aperture of the size of a man's arm. After securing the above hoods on the dishes, a quantity of the *arsenic*-meal is shot through the aperture into the dish, fire made in the furnace, and the meal directly sublimes into the hoods, being often stirred in the dish, by passing a stick through the aperture; and when a quantity has sublimed, they convey in more meal, 'till the hoods become sufficiently charged, and generally they let the fire in the furnace go out every evening, the aperture always remaining open: but the operators must bind up mouth and nose in charging and stirring the meal. Now, in order to procure yellow *arsenic*, amongst three centners of meal, between two and four pounds of sulphur are added, which being sublimed together, a beautiful yellow *arsenic* is procured *. Thus far M. Rosler.

IV. To

* Id. ib. Lib. IV. c. 18. p. 157. seq.

IV. To the operation of CRUDE-SMELTING.

The operation of smelting ores is the separation of the metals, first, from the parts, reducing metals to ores, namely, the sulphur, arsenic, and the unmetallic earth, intimately lodged in the ore-mixtion; and besides, from unmetallic, stoney, earthy matters, externally adhering thereto, and incapable of being washed therefrom. With us at Friberg, this operation is principally two-fold, namely, (1.) the *crude-working*; (2.) the lead-working, from which afterwards flows the copper-working. The *crude-working* is that wherein the ores in their crude state, that is, not only with the adhering unseparated mineral matters, but also in their unroasted state, are lodged in the furnace, and smelted with serviceable, fluxile slags, and the best or purest part of them brought to some degree of concentration, or to a regulus, called *crude-stone*. The lead-working, to which the above crude-stone is taken, after a previous roasting for three or four times, and the ore, employed therein, and which is mostly *glitter* or lead-ore, and rich silver-ore, is not only well cleaned, by picking, stamping, and washing, but has also undergone a number of roast-fires, and is well separated from the sulphur and arsenic. My only reason for comparing both these operations together is, that in the first, the ores are unstamped, unwashed, and unroasted, but in the second, well parted and roasted, without making any distinct head of our copper-working! as it coincides with, and also flows from the lead-working; where, namely, the *lead-stone*, that is, the crude copper cake, or regulus, settling down from the former, also after repeated burnings or roastings, when it comes to be denominated *copper-stone*, is

first smelted, and brought to black-copper, and this, at length, after separating or draining the silver, made pure or fine. Here I have only to make mention of the crude-working or smelting, as pyrites is used therein, and is, not only in this case, the principal agent, but also, in regard to its other uses, for sulphur, vitriol, and arsenic, here the most important thing.

Now the ores, when landed at the *day*, are first picked and sorted; what is quite clean and pure, as lead-glitter, black-lead; or very noble, as red-goldish or white goldish (though these are not always quite pure) is roasted, and thus directly taken to the lead-working; what is quite barren, rocky, and unyieldy, is thrown away. Not only in this picking, but also in veins, there is procured much of a middle degree of goodness, holding neither much in noble nor ignoble metal, but yet not to be entirely thrown away; for instance, first, highly rocky or stoney mixt-work, as quartz, spath, kneiss, horn-stone, cat-silver, Muscovy-glass, glimmer, and lime-stone; then also, in general, with us at Friberg, mock-leady matters, wherein, notwithstanding something of a good ore, in particular glitter, copper-ore, and even nobler matters, either in eyes, or interspersedly, or in the most tender fibres, and which can in no wise be separated with profit. For, to employ stamping and washing thereon, would not quit the trouble, or the metal would be wasted and lost, especially in the case of tender interspersed noble spangles; and equally unfit would such prove for roasting, as by that means the rocky matters, which here cause the only inconvenience, would not thus be removed or corrected. Now, in order to work such ores, the method of *crude-working* was devised, and is, hitherto,

thereto, found the best means for that purpose ; and therein the *pyrites* is the principal instrument, as by its means the heap-work, wherein the metal lies widely dispersed, is, by procuring the *crude-stone*, concentrated or brought within a narrow compass, and afterwards this stone duly worked by roasting and smelting, for procuring the metal-yield ; and after repeated roastings gives forth its silver by means of the lead-working, amidst leady ores, and the like *additions* ; but its copper in a crude, stony form, called *lead-stone* ; which last must by repeated roastings be reduced to *copper-stone*, and this again, by smelting, to black copper, before it can be made pure and fine. This crude-stone, with us at Friberg, generally contains between 2, 3, and 4 pounds of copper, and four loths of silver, and is accordingly dosed with *additions*. Now *pyrites* either lodges already in the ore, thus to be treated in its crude state, especially in coarse veins ; or is added on purpose, as found necessary ; or is entirely wanting, as generally in noble veins : and here it is so much the more needful to be added, as where no *pyrites* is to be had, or proves too expensive to be conveyed to the spot, most of the ore of such places, which is commonly interspersed with metallic spangles, very thinly sown, and, on that account, neither to be washed nor roasted, lies useless and unworked.

That the *pyrites* promotes at least the flux of ores, or rather of their rocky, stony, and earthy admixtures ; or briefly, helps to scoria and reduce them to glass, is its known effect in the operation of *crude smelting*. But when such rocky admixtures hold good ores, as of lead, copper, and the like, the use of *pyrites* is superseded, as the above are

are of themselves sufficiently fluxile : and that it is of no manner of service to rocky matters alone, may easily appear, upon dosing barely with *pyrites* such matters, were they without all eyes of ore, and were neither soft flags, nor any leady additions employed therein. And thus *pyrites* aids, or aids not, according as itself is or is not aided. It is in itself stubborn, yet becomes soft and flowing, according as it is treated or dosed : whence it is necessary to consider the refractoriness and easiness of ores in general to flux : and 'tis owing either to the ores themselves, or to their mineral admixtures. In themselves, *glitter*, white and green lead-ores, antimony and yellow *pyrites* or copper-ores are soft-flowing : but white *pyrites* more stubborn, yet smelting in a brisk fire, even when unstripped of its arsenic : more stubborn is the yellowish *pyrites*, which apart difficultly or not at all cakes : most stubborn of all is mock-lead, and next, the earths of *pyrites*, cobald and bismuth, or their *capita mortua* or remainders : yet those of the yellowish more than those of the white ; as the former hold more metallic, namely martial, but the latter, more unmetallic earth : Those of cobald and bismuth are highly unmetallic (so far as our experience hitherto goes) and hence not to be fluxed without salts, as we learn from the *smalt-glass* : and as ores hold these three metals, lead, copper, and iron, they in proportion prove either hard or soft flowing, as these metals themselves prove : for it is known, that unmetallic earths flow most difficultly ; iron, with difficulty ; copper, with more ease, and lead, with most. In regard to their mineral admixture, all ores are properly stubborn ; though quartz, compared with any other, scorifies *per se* with the most ease ; but with *additions*, particularly lead,

also

also in some measure arsenic, quartz and spathe, are very fluxile : much more stubborn are glimmer, Muscovy-glass, talc, cat-silver, shiver and horn-stone ; most of all lime-stone, gypsum, alabaster and chalk. All which particulars I have learned from the proofs. It remains to be enquired why *pyrites*, which is properly of the stubborn ores, is a flux, and in what circumstances. *Pyrites* is three-fold ; yellowish, yellow and white ; or iron, copper and arsenic *pyrites*. The white or arsenic *pyrites* is quite unfit for the operation of *crude-smelting*, and hence kept from it as much as may be ; in regard its arsenic eats away and scorifies the lead, which is already amongst it either in eyes of *glitter*, or lodged in the soft ready flags, or otherwise added thereto, as is well known of both these bodies : or again, when the arsenic has nothing to do with lead, it separates with difficulty, or not at all from its earth (as the *crude-working* is a strong smelting fire, wherein it directly cakes therewith, and rather requires a soft roasting fire for its separation) consequently the earth cannot scorify, as it should, to answer the end of *crude-smelting*. Again, this inconvenience happens, that the arsenic, lodging in the iron of the *pyrites* earth, will not be separated from it in the following lead and copper workings, but is still to be separated in that arsenical, iron mafs, called *speise* and *leg*. Further, its earth is so crude, as to become, if not unserviceable for scorification, the principal thing here intended, yet not so easy-flowing ; especially as the white *pyrites* is so overdosed therewith : and again, it gives none, or but an arsenical, impure *crude-stone*, or *regulus*.

But the yellowish and yellow ; or, as they are cal-

called at Friberg, the sulphur or iron *pyrites*, and the copper-ores are what deserve particular mention here for the operation of crude-smelting, and most peculiarly, the yellowish, as what so completely answer, as to compensate their want of copper : Though indeed it were better, were the common *pyrites* not only coppery, as it generally is at Friberg, but also were copper ore added ; as then we might expect a *yield* of copper, to help to compensate the charges in working ; and in some circumstances, indeed, where the work shall prove hot and refractory, cannot be omitted without loss in silver-yield , but in itself, and for promoting the principal end of this method of working ; that is (1) For the scorification of the rocky, stony, and earthy matters. (2) For making the *stone* or *regulus*, and concentrating the silver, it cannot be considered as absolutely necessary ; as it promotes not the first ; and as to the second, lead is sufficient ; which is already in the ore in *glitter-eyes*, as coarse veins are never without them ; or leady *additions* may supply that want for noble veins ; where not only *glitter*, but also *pyrites* is generally wanting.

What the *pyrites* contributes in the operation of *crude-smelting*, is to flux and scorify the stony and earthy matters, to separate the ore from them, and make it give forth itself in what is called the *stone*, or *crude regulus*. Now as *pyrites* consists of several parts, as sulphur, arsenic, iron and copper, we must enquire which of these it is, that promotes the above effects. The arsenic is here to be secluded, as corroding lead, tainting silver, and as encumbering, nay proving detrimental to the scorification. Copper is in this case to be consider-

sidered rather as a *patient*, and so far good, than as an *agent* in any degree : consequently, there remain only sulphur and iron, which from all circumstances and experiments we may conclude to be the principal agents in the business of the separation, precipitation, scorification, or by whatever other name the process be denominated. That the sulphur contributes not a little, we may certainly conclude from desulphurated *pyrites*, never yielding any *stone* or regulus ; and so being unfit for the principal view of this operation. Its efficacy appears chiefly on the rocky, stony, and earthy matters, adhering to the good ore, or wherein rather the good ore lies entangled. The large quantity of crude, unmetallic, unfluxile earth, which is not to be forced by the addition of soft flowing scoriae, wants something, which, with the aid of the sulphur of the ore itself, may macerate, soften, dissolve, and bring it to scorification ; an effect depending certainly on the acid salt of the sulphur : but though spirit, or oil of vitriol act little or nothing upon stony and earthy matters ; yet we are not from the effects of bodies in their separated, to conclude to those of their mixed, state : oil of vitriol, or of sulphur, as distilled from vitriol or sulphur, has a different habitude from what it has, while lodged in the sulphur, and combined with the inflammable earth, and still as different as it ; nay, the sulphur itself stands in the *pyrites* *mixtion*.

As to the second, the iron ; its necessity of co-operation appears clearly hence, that (1) The sulphur is, in its separated state, entirely unfitted for the process of smelting, and would only burn away too soon. (2) That in another, even a combined state ;

state ; for instance, in antimony, where there is certainly no want of sulphur, it would not once work in due manner on the rocky matters ; since the sulphur in the antimony does not by far so easily separate from its semi-metallic earth, or regulus, as in the *pyrites*, from the iron-earth, and thus would fail to exert a due degree of activity ; not to mention, that the sulphur should help to scorify in the manner the iron does. Besides, the iron has to do with something more than the unmetallic earth, namely the *ory* matters ; which last cannot, or, at least, not so well, be affirmed of sulphur ; namely (1) The *pyrites* iron, under the direction of proper *additions*, especially leady flasks, also leady ores, helps to make the *stone*, corroded by the sulphur, soft and fluxile, and at the same time becomes itself soft and fluxile therewith, that is, a glass or flag. And this proceeds (1) From the easier *terrification* of the *pyrites* and iron itself : but the terrification, or reduction of metallic bodies to earth, is the high way to their vitrification, and scorification, is a species of vitrification. (2) By this means, the good ore, dispersed and spread abroad, and as it were immured in the rock and earth, is set free and fitted for metallisation. (3) The iron, which before was a captive to, but now is released from the sulphur, strikes the sulphur and arsenic out of the ore ; nay swallows them up, so that the metal is thereby freed from these gross impurities, or precipitated, as a regulus out of antimony. All which internal elaborations, marked under these three heads, we are to suppose to happen instantaneously, or with a quickness equal to the violence of the fire. But as no separation and precipitation happen without the *separant* entering into the *separand* ; so here all the *pyrites*-iron goes not into the

the slag or scoriae ; nay mostly, or in an unknown proportion, combines with the *crude-stone*, as being ever found to be irony.

Now from what has been said, we may form a judgment of a *crude-smelting*, wherein sometimes iron-stone, sometimes real or corporal iron itself is employed ; of which, among others Lohneiss makes mention. It is true, we cannot with proper grounds speak of such a method, if we are unacquainted with the whole dose of *additions*, and with the ore : as little will I affirm, that in some circumstances it may not hit ; yet not be unattended with great difficulties, not easily surmountable. Though thus much I see from my own experience, that iron very readily *regulates* or metallises *glitter*, as proving here the most adapted *separant*. But (1) Our business, especially in the matter of *crude-working*, is not with pure *glitter*. (2) Should the iron supply the place of *pyrites*, nay, have a better effect, the stony matters would remain untouched, as being to be fluxed by the sulphur, which is in the *pyrites*, but not in the iron. And lastly, we should consider how it affects the goodness of the copper and lead. With the iron-stone to procure the principal end of the *crude-working*, which consists not only in separation, but in scoriification too, the more art is requisite ; in that this last, on the score of its incorporated stubborn crude-earth, and impurity, wants for itself the proper aids and helps. Briefly, it holds quite otherwise with the *pyrites* iron, than it does with smelted iron and iron-stone. In the *pyrites* it is not only adapted in a certain manner by nature, but becomes more so in the course of the operation itself ; turning to a spongy, subtle earth, both receptive, and

and operative ; a thing not to be expected from iron-stone. And he, who has experienced the different habitudes of bodies in their simple, separated and mixt states, will view artificial iron, and the iron-earth of *pyrites* in different lights.





C H A P. XVI.

Containing, I. The history of the Hessian Pyrites, called *Terra martis Hassiaca*. Communicated by M. Rosinus.

GREAT Almerode, a considerable village in Lower Hesse, three miles from Cassel, and five hours ride from Munden, lies in a very mountainous, and almost the highest part of Hesse, and is encompassed on every side, partly with very tall forests, partly with very high mountains, among which last the Weissner and Herfs, or more properly Hirschberg, are the principal. The Weissner, which is the highest in all that country, rises near the village of Ludenbach, an hour's ride from Great Almerode, and contains a large inexhaustible store of stone-coals, which are there dug in two different places, and conveyed to Altendorff for boiling salt: besides, on its top, which is quite a plain, a mile in compass, many peculiar herbs grow, not readily to be met with elsewhere, also good pasture-grass. The Hirschberg, which is close by Almerode, abounds much with bituminous fossile wood, or wood-coals, as they are called, also with plenty of good bituminous alumore, for which two alum-huts are built at its foot. The ruggedness of the country, and inclemency of the weather, thence arising, prove prejudicial both to the agriculture and horticulture about Almerode, the garden-fruits arriving very late there to their perfection and maturity; as I once remem-

ber

ber to have seen there, about Michaelmas, a tree with ripe cherries upon it: tho' whatever the country about Almerode may seem to want in this respect, is sufficiently compensated by other advantages; among which we may chiefly reckon the various sorts of clays found there, and called sometimes *crucible earth*, sometimes *pipe*, and sometimes *pottery earth*, according to the various uses they are put to. The pipe-earth is mostly employed by the tobacco-pipe makers of Almerode, Cassel, and chiefly of Munden. The crucible-earth, worked at Almerode itself, gives, by mixing amongst it a coarse, dry sand, those crucibles and retorts, which, for their standing the fire, are famous all over the world, and with which those of Almerode carry on a considerable traffick, by sending yearly whole ship-ladings of them to Bremen, Holland, England, Dantzick, Riga, and other Parts. From the pottery-earth, besides the common earthen vessels, are made those stone-bottles, which are yearly sent in large quantities to Pyrmont, there to be filled with water, and conveyed thence far and near. Among all the abovementioned sorts of clay or earth, are also found various kinds of *sulphur-pyrites* kidneys: those in the white pipe-earth appear in various angular forms; and, as the clay-diggers affirm, are assayed for silver and found *yieldy*. Upon breaking them, they often appear white like the arsenical *pyrites*, and as it were, of a silvery cast; are remarkably ponderous, and either do not at all, or at least it is in a very long time, and, with the greatest difficulty, they crumble in the air; as I have had some exposed for seven or eight years, and in all that time, only some small vitriolic efflorescences observed on the upper surface.

face. In this pipe-earth, which is dug very deep, are sometimes found fossile galls over the *pyrites*, or at least foreign fruits entirely resembling galls. In the greyish crucible-earth are also found *sulphur-pyrites*, though seldom, and in small bits and grains only, but which the crucible-makers carefully pick out from among the clay, because if left behind, they would render the vessel, made from the clay, perforable in a strong heat, and unserviceable : of this *pyrites* the workmen affirm it resolves in the air to vitriol : tho' very slowly, the dark grey potter's clay is properly that earth, which holds the famous *minera martis solaris*, thus magnificently styled by Glauber. The place, where these *pyrites* are found, is at the foot of a hill, not far from the village ; where, together with the said potter's clay, in which they lie strewed up and down with some other *coagula* or *druse* of Muscovy-glas, they are dug out at a small depth, almost at the day, and found in such plenty, that I myself, and two other persons, had in about one hour and half, with ease, gathered a centner of them : their figure generally, as that of the like *coagula*, is more or less round, also oval ; externally they are of a blackish cast, but internally of yellowish, most frequently of a paler, but sometimes also of a darker hue than other *pyrites* ; and in gravity and hardness differ nothing from the other *pyrites* abovementioned. Only in this they seem to have something peculiar, that they not only entirely, but also (which chiefly deserves to be considered) very soon resolve spontaneously in a moist, open air, and crumble to a greyish powder, which after elixation and evaporation, yields forth a green iron-vitriol, and an acid liquor. 'Tis true, I am acquainted with *pyrites* enough, which in time change to a vitriolic salt ; as such are found in

great variety near Almerode, also in the clay and blue marl pits of Munden, and other adjacent places ; yet I know of none undergoing so speedy a change as those Almerode *pyrites* found in the potter's clay : since I have been assured by persons of credit there, that being dug fresh in summer weather, and moistened a little by means of a warm rain, and afterwards lodged in a shady place in the open air, they vitriolise in a few days. Last summer I observed a phænomenon entirely uncommon, and perhaps peculiar to the *minera martis sulphurea*, rather than *solaris*, of Almerode : namely, that having placed a large wooden trough with this mineral, most of it being already become a vitriolic powder, on a floor four story high, which was indeed dry, but sufficiently exposed to the air, fanning though the open windows. In the beginning of the summer, I unexpectedly observed this matter to become moist, and gradually still softer, nay lastly, fluid, and begin to trickle through a small rent in the trough. Upon which this fluid matter, together with its thick bottom, was put into other vessels, and by the addition of more water fully elixated. The clear lie being poured off, was put into open, flat glasses, and committed to the gradually increasing summer heat, till become quite dry : by this means I in some time procured from this liquor a green vitriol, and a yellowish dry bottom or settlings, easily pulverable. But in the immediately succeeding autumn this dry bottom was deliquated anew, and changed to a fluid matter, not unlike, in colour and taste, an unrectified oil of vitriol, in which state it continues to this day. There moreover appears in the course of the crumbling of this *pyrites*, a circumstance altogether peculiar and very memorable ; namely, that it

then

then (most of all, that which resolves the soonest) heaves or ferments, as it were, from within outwards, comes to have cracks, and thus gradually falls asunder, and acquires a vitriolic salineness. Whence it clearly appears, such fermentative, intestine, dissolatory motion must needs originally arise in the very center of the *pyrites*. In the *conchites bivalvæ* of Landwernhage, which are still covered with their close natural shells, but internally filled with *pyrites*. I observed in what manner, some, before ever any thing vitriolic could be observed in them, snap asunder in the middle, and open quite wide, in such a manner, as that the hinges, wherewith the shells still remained joined together, stand directly opposite to each other, which can be ascribed to nothing but the above mentioned cause. Further, some authors have remarked, the *sulphur pyrites*, both in the groove and elsewhere, when lying moist and heaped high on each other, usually to heat from within outwards. And in order to try, whether the same would not hold of the *pyrites* of Almerode, I took between 50 and 60 pounds thereof fresh dug, and stamping them to the finest powder, I moistened this powder gently, and shot it into tall glasses, prepared expiely for the purpose ; and tho' left standing open for some time in the free air ; yet it did not discover the least degree of heat or warmth : nay, the *pyrites*, thus moist and laid high on each other, would not even bewray the least change, or yield the least vitriol : whether the time of year, as it happened to be October, was unfit for this experiment, I shall not pretend to determine. This very experiment I repeated in another manner, putting small powdered *pyrites*, moistened with brandy, into a low cucurbit, to which I fitted a large helm and receiver, in no case

to

to lose the brandy passing over; which even then, without raising any degree of warmth in the *pyrites*, began mostly in the night time to re-distil over, though slowly, there being, for weeks together, not above half a pint procured: this brandy tasted something of the *pyrites*, and was very phlegmatic; whence I conjecture, not only the bare nocturnal cold, but also the intestine heat of the *pyrites* to have contributed something to its passing over. Be this as it will, thus much at least we may learn from the resolution and vitrification of the *sulphur-pyrites*, that in it is certainly included something highly prone to intestine motion; and to be sought for either in the common sulphur or the iron; of both which we know the *pyrites* consists. The phænomina arising from artificial and natural productions, combined with sulphur; for instance, phosphorus and the bituminous alum ores, which take fire in the open air, and resolve to alum, should almost persuade one, that the sulphur ought to be considered as the principal cause of the vitriolescence of *pyrites*: and accordingly I understand the matter thus; the inflammable substance combined with the sulphur of the *pyrites*, is itself by the access of the external moist air, not only first excited, and then the whole concrete put into motion by it, but moreover is still more and more freed, and at length quite separated from its union with the acid; consequently, such acid, after a perfect separation, unites with the iron, and forms a vitriol. By way of conclusion, I add that no one, so far as I know, has hitherto written of the *vitriol pyrites* of Almerode, nor are there any vitriol-huts there. 'Tis true, the alum-boilers prepare from their lie, precipitated by means of urine, a green vitriol,

but

but so poor as to be sold very cheap, it being but little valued. Thus far M. Rosinus,

II. The specific gravity of the PYRITES.

As I myself was without a good hydrostatical balance, I in this case applied to the celebrated Dr. Meuder, who readily gave me his assistance here, and not only examined the *pyrites* and its concomitant matters in the most accurate manner possible, and with repeated care and diligence, but also many others, and those the principal, both dense and fluid bodies, as laid down in the following tables ; to which he has subjoined a set of uncommon remarks and principles, and peculiar ways of managing the hydrostatical ballance. The small table of *pyrites*, sulphur, arsenic, &c. might have seemed sufficient for my purpose ; but as this is a subject hitherto not so fully and fundamentally examined, the reader will not be displeased if I give the tables at length ; the specific gravity of the *pyrites*, and its concomitant matters deserving the utmost regard, and a subject being ever best illustrated by comparison with other matters. Dr. Meuder goes on thus.

As the specific gravity of each body is deemed to be one of its characteristic marks, and as such observations may be supposed of further physical use, we have given the following tables of the specific gravity of the principal and most known mineral bodies.

- 1 Transparent amber.
- 2 Colophony.
- 30 Brown pitch.
- 43 Black pitch.
- III Asphalum.

- 244 Pumice-stone, full of water.
 274 Stone-coals.
 296 Gum-arabic.
 418 Aphronitrum.
 430 Hard gypsum, full of water.
 438 Red tartar, full of water.
 533 Crude sulphur.
 545 Purified sulphur.
 546 Fossile opal.
 556 Sulphur, once melted over.
 556 Fossile sulphur.
 559 Stone-marrow, or lac lunæ, full of water.
 559 Crabs-eyes, full of water.
 568 Brown glimmer.
 601 White Indian porcelane.
 611 Facitious black-lead.
 616 Sweet vitriol-earth, out of the Minera
 martis Hassiaca.
 618 Cat-silver.
 624 Lapis specularis.
 630 Bricks, full of water.
 630 White misnian porcelane.
 635 Red Japan porcelane, full of water.
 639 Crystal-glaſs, of burnt flint and saltpetre,
 equal parts.
 642 Stone from the Prudel, at the Carlsbad.
 648 Chalk, full of water.
 658 White Bohemian glaſs.
 661 Variegated glitter-glaſs.
 668 Red coral.
 669 Common blue glaſs.
 674 Red bole, full of water.
 676 Green glaſs, with one eight verdegrease.
 677 Amianthus from the Serpentine quarry
 near Zoblitz.
 678 Alabaster.
 679 Dresden crystal-glaſs.

680 Oblong

- 680 Oblong belemnites, full of water.
 680 Horn-stone.
 681 Ophites, or serpent-stone.
 681 Coral-stone.
 684 Lapis Lyncis.
 685 Stone from the vineyard, from Malaga.
 685 Cornu Ammonis.
 687 Hungarian marbled diamonds.
 689 Drusiform mountain-crystal.
 690 Ruby-glass.
 691 Chalcedon, near Zwickau.
 692 White marble.
 693 Martialised oak-wood.
 695 Agat.
 695 Quartz.
 696 Elbe flint-stone.
 697 Cologne chalk.
 698 Red jasper.
 699 Pietra di Venturino.
 699 Mother of pearl.
 705 Shiver-stone.
 705 Sulphur flags.
 707 Black soft grind-stone.
 709 Red marble.
 709 Blue iron-slags.
 713 Lime-stone.
 716 Ætites.
 718 Quartz, near Rudelstadt, in which there
 is native gold.
 722 Soft ruddle, full of water.
 726 Violet-stone.
 727 Alumen plumosum.
 738 Granate-ore, near Pirna.
 759 Razor-hone, soft and white.
 771 Red arsenic, or sandarach.
 781 Fossile verdegrease, or chrysocolla.
 784 Highly red sandarach.

- 785 Dingy sandarach.
 796 Cadmia fornacum, for brass.
 807 Orpiment.
 813 Iron-scales.
 821 Smelted luna cornua.
 827 Fossile black-lead.
 828 Lapis de tribus.
 833 Yellow arsenic.
 834 Magnet, full of water.
 837 Small granates.
 838 White arsenic.
 841 Pyrites from the Croner.
 843 Yellow pyrites, from Lorentz.
 844 Ordinary, or poor cadmia fornacum.
 848 Blend, or mock-lead.
 849 Copper-ore, from Temeſwaer.
 854 Ceruss, full of water.
 858 Hungarian copper-ore.
 858 Common antimony.
 861 Copper-ore, near Rudelstadt.
 863 Yellow pyrites, from Neustadt.
 863 Large granates.
 863 Ore of antimony.
 864 Close black iron-stone, from Kuhnheyde.
 865 Yellowish pyrites, from the Hartz.
 870 Blendy, or mock-lead y cadmia fornacum,
 871 Tinny black-lead.
 873 Pyrites-balls, from the Andreasberg.
 883 White spath, from the Seegen-Gottes.
 884 Toplitz pyrites.
 891 Pyrites from the Geyer.
 892 Pyrites from Temeſwaer, full of water.
 895 Snail-cobald from Schneeberg.
 897 Bohemian granate-ore.
 900 Blood stone, or glass-head.
 905 Pretzschendorff pyrites.
 906 Factitious fly-stone, full of water.

- 907 Yellowish pyrites, from Johan-Georgenstadt.
907 Yellowish pyrites, from the Halsebrucke.
908 Yellow pyrites, from Sweden.
912 Minera martis Hassiaca.
914 Yellowish pyrites, from Sweden.
915 Glass of antimony, made *per sc.*
916 Yellowish pyrites, from the Ehrne-schlange.
917 Yellowish pyrites, from the Zug.
919 Close, or firm pyrites from Temeswaer.
924 Hungarian quicksilver ore, full of water.
940 White pyrites, from the Himmels-farth,
and Gunther.
945 Glass of lead.
955 Cinnabar, fixed with silver-filings.
956 Testaceous-cobald, or fossile fly-stone.
959 Smalt-cobald, from the Seegen-gottes.
962 White pyrites, from the Kuhschacht.
966 Transparent red-goldish ore.
968 Smalt-cobald, from Schneeberg.
975 Glassy ore.
976 Bismuth-ore, dove-necked.
978 Regulus antimonii stellatus.
980 Repeatedly purified regulus of antimony,
with twice the quantity of iron.
989 Tin-stone.
990 Clear lead-glitter, or galena.
991 Cobald, near Rudelstadt.
993 Zink.
993 Regulus of antimony, with twice the
quantity of copper.
993 Snail-cobald.
997 Coarse lead-glitter.
997 Fine tin.
999 Coarse mineral cinnabar.
1001 Common, or alloyed tin.
1002 Kupffer-nickel.

- 1003 Mineral cinnabar in grains.
- 1003 Speise from lead-work.
- 1004 Drusiform lead-glitter.
- 1005 Diced lead-glitter.
- 1006 Factitious cinnabar.
- 1007 Iron.
- 1009 Silver-litharge.
- 1013 Speise, of four parts zink, and one part copper.
- 1022 Brass.
- 1022 Malleable prince's metal, of copper and cadmia fornacum.
- 1026 Silver alloyed six parts.
- 1028 Copper.
- 1029 Bismuth.
- 1046 Silver.
- 1058 Villach lead.
- 1073 Quicksilver.
- 1098 Gold.

Remarks on the HYDROSTATICAL BALANCE,
and its use.

I. For a balance to be sensible and accurate, that is, constantly to shew, in an uniform manner, the same degrees, the stem must be hollow and open a-top, for the air in the body below to have a constant free communication with the external air.

II. Consequently, such are unfit whose stems are either not hollow, or yet are close a-top; as the common glas and amber sort.

III. The longer the stem, the better; as then the greater number of degrees may be marked thereon, and the more different bodies it can bear, without sinking down.

IV. The

IV. The stem must also be of equal thickness and strength throughout, otherwise it sinks not down straight, proportionally to the weights applied.

V. The best figure for the lowermost body of the balance is the conical, as such, may with less resistance force through the fluid.

VI. The lines, or degrees on the stem, must be made accurate and equal to each other, and one tenth of an inch is a proper measure, or standard to divide by.

VII. To the cone, or belly below, there is a perforated scale of a balance appended, for the fluid to pass through, and thus the true degree of gravity not to suffer any alteration. These small perforations, however, have not hindered the weighing of running mercury, without the least of it straining through.

VIII. The very balance wherewith the above remarks were made, has a stem of nine inches, each divided into ten parts, making in all ninety divisions; with one grain of fine silver, it sinks six lines, consequently bears in all (from one to a ninetieth degree) only fifteen grains; whereas my amber stem, eight inches long, and containing eighty lines, scarce sinks one line with one grain of silver; and thus the first is six times more sensible than the second. A grain I call the sixty fourth part of a drachm, namely, the piece which is marked with sixteen standard penny weight.

IX. A difficulty still attending a balance so sensible is, (as then it must be sensible for the observations) that very few bodies can be weighed by it; for the most either quite sink the balance under water, or leave it quite a-float a-top, so as not to sink at all; as, among all the above bodies, scarce ten have, barely of themselves, shewn their degree of gravity. But this difficulty may be easily obviated, by correcting the levity and gravity, by the adding and taking away of weights, and then calculating how many degrees such weights make out, and how much must be added or deducted.

X. The fluid wherein you weigh must be constantly one and the same, also be of the same degree of warmth, or of cold; whence, in winter, the degrees appear not the same as in summer, even though the very same water be used.

XI. The degrees on the above balance must be counted from below upwards, as these must increase with the encrease of gravity.

XII. All the bodies you would weigh are previously, by means of a pencil, to be wetted with water; otherwise the air-bubbles adhering to the body under the water, make it lighter than it is.

XIII. Also all porous bodies, as crabs-eyes, chalk, &c. must be suffered to absorb their fill of water; else also the body proves lighter than it really is.

XIV. In regard to artificial, and other bodies, care is also to be had, that they contain no included

cluded air, which cannot be discharged; as is often the case with cast sulphur, and also the *ærites*.

XV. At last, all the bodies must be weighed, in the most accurate manner, on an assay-balance of equal weight, one grain thereof answering exactly to six lines: all bodies, weighing three drachms, have, for the above observations, been weighed with the utmost accuracy.

XVI. But for examining the comparative gravity of salts, as alum, borax, vitriol, sal-gem, &c. instead of water, rectified spirit of wine is to be used, as not dissolving therein in the course of the weighing.

XVII. In order to weigh a costly body, of which a heavy piece cannot be had, or if too heavy, none of it can be struck off, look in the table for a body approaching tolerably near to it in specific gravity, and of this last weigh, on the assay-balance, an equal weight against the costly body; then weigh both in water; lastly, add to or subtract their difference from the known body in the table, according as the costly body happens to be lighter or heavier, and you procure the true specific gravity of the costly body, by the proportion in the table.

A curious and useful contrivance for ordering a tall cylindrical glass in such a manner, that upon pouring into it an unknown saline water, the hydrostatical balance shall instantaneously, without a calculus, shew the number of grains or drachms of salt in a pound of the saline water.

(1.) Cause to be made a tall cylindrical glass, about twelve inches high, and two and a half thick;
(2.) fill

(2.) fill it up with running water; (3.) append to the cone of your balance so much fine tin as shall sink nearly under, yet with its uppermost point appear above the water; (4.) mark the place on the glas, where the upper edge of the cone stands: (5.) now dissolve in four pounds of such water, one loth, or half an ounce of common salt; (6.) with the salt-water fill the cylindric glass to the preceding height of the common water; (7.) hang your balance therein, as before, and when it comes to rest, mark again, where the upper edge of the cone stands below; (8.) divide the distance between the two points marked, into sixty equal parts (each of which is to shew a grain) and write the numbers from below upwards; (9.) and thus the balance will, with its upper edge, shew the number of grains of salt in a pound of each saline water, upon filling therewith the cylinder: (10.) but if the balance refuse to sink, 'tis a sign there is not above a drachm in one pound of the water: hence mixing one pound of the saline water with one of common, and then, in the manner above, examining this weakened water, and doubling the grains found, you again procure the true *yield* of salt.

The gravity of different fluids compared.

- 300 Rectified spirit of wine.
- 332 Pontack.
- 333 The Weiferitz-water.
- 333 The Wolckenstein bath-water.
- 333 Rhenish wine.
- 334 The Radeberg bath-water.
- 334 New Mifnian wine.
- 335 The Fress-water, near Graupen.
- 336 The cold Caroline Prudel-water.
- 357 The cold Caroline Muhl-bath-water.

- 339 The Zedlusch bitter water.
- 341 The sound urine of sanguine constitutions.
- 343 Cow's milk.
- 343 Dresden beer-wort.
- 344 Dresden double beer.
- 348 Affes milk.
- 361 Red Misnian must.
- 374 Common spirit of salt.
- 378 Common small *aqua fortis*.
- 391 Common good *aqua fortis*.
- 516 Oil of tartar, *per deliquium*.
- 606 Common oil of vitriol.
- 4500 Quicksilver.

But as at present our principal view is to the *pyrites*, we shall bring it, in its kinds and appendages, with a reduction of the numbers, into the following table apart.

- 1 Crude sulphur.
- 12 Purified, or common sulphur.
- 23 Fossile sulphur.
- 23 Once-melted sulphur.
- 172 Sulphur-flags.
- 251 Red arsenic, or sandarach.
- 274 Orpiment.
- 295 Lapis de tribus.
- 300 Yellow arsenic.
- 305 White arsenic.
- 330 Yellow pyrites.
- 375 Yellowish pyrites.
- 423 Fossile fly-stone, or testaceous cobald.
- 429 White pyrites.
- 435 Smalt-cobald.

Thus far Dr. Meuder.

We then see how *pyrites*, and its sulphur and arsenic, compared together, and with other bodies

dies, stand related in specific gravity; and by this means not only learn to discover the nature of the respective bodies: for instance, that arsenic approaches extremely near to the nature of metals. We are also hereby furnished with a test to judge of the relation between this and other bodies in the first table, which may be safely depended on: for thus, a sulphur, the more arsenical it is, the heavier; an arsenic, the more sulphureous, lighter than a white crystalline arsenic; and an orpiment must contain more of arsenic than of sulphur; a *pyrites*, and an *arsenic pyrites*, the heavier, the more arsenical, &c. Only it is well to be observed, (1.) that the body to be examined have not the least foreign admixture, as stone, earth, or other ore adhering; (2.) be not fibrous and porous, but close or dense, for the air not to lodge entangled in it, or, notwithstanding, being capable of being exhausted, as both these circumstances render the proof fallacious. This, for instance, is the reason why crude sulphur appears lighter than purified sulphur; whereas crude sulphur, when of a grey cast, as this was, and generally is, holds a little arsenic, and though never so little, it must at least preponderate purified sulphur. Further, fossile sulphur weighs more than purified sulphur, the latter not being so close or dense as the former; whence that sort melted once more over, and thereby becoming closer, is heavier than the purified. Yet closeness, or density and gravity go not always hand in hand; flint, for instance, is lighter than quartz, and this much lighter than spath: white crystalline arsenic is much lighter than fossile fly-stone, which sublimes entirely in form of a white arsenic, whence the crystalline arsenic must either have acquired or lost something, which must needs have made it lighter. Nor need we wonder that yellow, or copper *pyrites*, is

is lighter than yellowish, or iron *pyrites*, though the latter consists only of iron and sulphur, but the former of copper and arsenic (at least more than the latter) which are heavier than iron and sulphur; and from this we must needs conclude *copper-pyrites* to hold more unmetallic, consequently more light earth. But, to say the truth, the hydrostatical balance is far from being that absolute means of attaining to the entire and full knowledge of bodies, which some philosophers, who might be too nice to smut their hands with chemical processes, would have us to take it for, whatever short auxiliary means it may otherwise be: nay, nor this balance, nor the fire alone, nor air, nor depart-waters alone, nay, often, not all of them together are sufficient to disclose to us the secrets of nature.

III. *Miscellaneous Observations and Experiments on the PYRITES.*

I. Native silver is most commonly found either in pure quartz, or near and on cobald, and consequently on an arsenic-ore; though *misspickel*, or *arsenic-pyrites*, equally with cobald, be arsenical, yet we have hitherto had no instance of native silver thereon, which must be owing to its iron, or other earth, hindering the production thereof.

II. Native gold is, in like manner, commonly found in pure quartz, never on cobald; whereas, on the contrary, 'tis to be found on *misspickel*.

III. On yellowish and yellow *pyrites* we find nor gold nor silver, at least, not as growing from such *pyrites*.

IV. I have been lately shewn a sample of *kneiss* with yellowish *pyrites*, and capillary silver lying thereon, as if the silver grew from the *pyrites*; but

first, it follows not hence, that because it lay on, it therefore proceeded from it: again, though we should allow this, yet it must needs be ascribed to the arsenic, this *pyrites* being hemispherical, and thus arsenical, like what we call *cobald*, at the Halsebrucke.

V. Nay, this sample would seem to shew, that the native silver comes to be *weathered* or destroyed again. 'Tis true, this I cannot conclude from the footy appearance, which, though in itself of some consequence, yet is not to be depended on, as this or the like sample would require an observation of many years; as, whether in that time the silver may be destroyed again, and in what manner; at least, 'tis a thing not readily credited by every one; and the crumbling and falling to pieces of the sample, is well to be distinguished from its *weathering*.

VI. Should native silver happen to be *weathered* again, it must needs be arsenical; in the manner it is affirmed, that native gold is often mercurial, and thus pale.

VII. It is true, *pyrites* is the mother of vitriol, but neither the mother, nor a recrement of metals, as was formerly thought *, but an ore *per se*.

VIII. As to what is said of the existence of gold in an Hungarian vitriol, communicating itself to the depart-water prepared therewith, it proves a self-deception, arising either from the experiment, or the judgement formed upon it: for, though the mint-master in Becher had found gold in it, it would neither be a fixation, nor an extraction, but a production, rather of a thing existing in neither of the matters employed, but produced from both †.

IX. Cane-

* Canepar. Desc. I. c. 2. Ludov. de Comit. de Met.

† Tollii Epist. Itiner. V. p. 175. Becher. Phys. L. 1. Sect. 3. c. 3. p. 142.

IX. Caneparius § pretends to have seen with his own eyes, rubbed marcasite, or *pyrites* changed, by pouring on vinegar, to quicksilver; which well agrees with what I adduced above from Boyle, at the close of chap. XIII.

X. Pomet was assured, a certain abbot had, from a certain marcasitical vitriol-yielding *pyrites*, to be found in the clay-earth near Passi, a mile from Paris, prepared his *universale*.

XI. That *pyrites* is of a mercurial nature, Albertus affirmis may be concluded from its giving to copper a white colour ||.

XII. Matthesius mentions a marcasite holding quicksilver and an arsenic ore (cadmia) from which, upon striking, there squirted out quicksilver §§.

XIII. How to draw quicksilver from vitriol, see Caneparius. ††.

XIV. Calx of lead digested with fal ammoniac, salt of tartar, and stale urine, and at length distilled, yields an arsenical odour, nay, at last, a beautiful phosphorus.

XV. I have had from Neusol, in Hungary, a white salt, under the appellation of a white vitriol, there called *strep*, of an oblong, tender, crystalline form.

XVI. The Radberg-bath comes from a *pyrites* extremely pure, above all other groove-*pyrites*, in iron vitriol.

XVII. In Sweden, in the large copper-groove at Fahlun, there was found, as Leyel ** relates, a man's body, which had lain there for forty years at

B b 3

least,

§ De Atrament. Descr. I. c. 10. p. 63. It. c. 18. p. 108.

|| Ludov. de Comitibus de metallis, p. 236.

§§ Libavius de natura metall. Lib. I. c. 1. p. 7.

†† P. 218.

** Acta Lit. Suec. Trimestr. prim. an. 1722. p. 250.

least, not only fleshy, uncorrupted, and sweet, but also sheathed, and done all over with vitriol, in manner as if candied.

XVIII. But to see how corrosive things, as vitriol, which destroy not, nay, rather preserve dead bodies, are more active and operative on living ones, we need only recollect what is practiced by the Easterns, who shave themselves with a mixture, consisting of crude earth and orpiment; yet, if care be not had, come to have their flesh perforated, or their skin become like Cordouan leather ***.

XIX. To try the effects of vitriol on vegetables, I dissolved vitriol in water, wherein I soaked ten grains of barley for twenty four hours, then letting them dry, they became quite black. Of these no more than two came up, with very weakly stalks, and small ears. Whether this was owing to the vitriol, or the great degree of drought, having planted them a little too late, I know not; yet vitriol appears to have but little fruitfulness in it, especially from the vitriol-earth at Rogau in Silesia, which being at first employed as a manure, rendered the fields barren *.

XX. Dr. Gould, of Oxford, has observed, that oil of vitriol does, by means of the air, encrease in weight, having, for that purpose, exposed a highly dephlegmated oil in an open wide glass, and weighed it accurately every day. In the space of fifty seven days, three drachms of oil of vitriol came to nine drachms, thirty grains. The first day the oil increased one drachm and eight grains, afterwards, from day to day, still less, nay, the last day, scarce half a grain. This succeeds in moist foggy weather better than in dry, also in a wide than narrow vessel †.

XXI. To

* * Tavernier's *voyages*, p. 166.

* Bresl. natur-und. medicin-geschichte im jahr, 1718. Jul. p. 1402.

† Phil. Trans. N^o 156. p. 496.

XXI. To shew the volatilisation of metals, Mr. Boyle alledges the following experiment: if you distil thin copper-plates with an equal, or twice the quantity of mercury sublimate, there remains something below, running, and inflammable, like Spanish or sealing-wax, which being powdered and exposed to the air, then saturated with spirit of salt; yields something like a verdigrease; and this, again, distilled with tripoly, or the like, gives a clear liquor, like spring-water, which turns green with sal ammoniac, or a volatile salt §.

XXII. Swedenberg has, in a *prodromus*, attempted to discover, in a geometrical way, and by the hydrostatical balance, the nature of bodies; but such conclusions, however, appear to me to be premature, it being necessary, first of all, not only to repeat and verify several, but, much more so, to make new experiments.

XXIII. In the Salberg-groove, in 1696, some running quicksilver was found, but never at any other time; also once, some in Lapland §§.

XXIV. As I was concluding this impression, I had some *pyrites* sent me from Alonitz, in Russia, of which I shall only say, that it differs not from other *pyrites*. The copper-ore in the Schiniselgi-groove, which is lafulous, holds forty five pounds of black copper. At the groove Bogatvi Mednoi Jamii, also at the Niniselgi Knordu, there breaks a fine quartz with native copper: and which is very remarkable, in the district of Nerzinskoy, in the groove Bajatky, there is found a fine-grained glitter, or galena, containing eighty five pounds of and four loths of silver.

XXV. Take one pound of *marcasita aurea*, says Mazotta **, and dissolve it in two pounds of de-

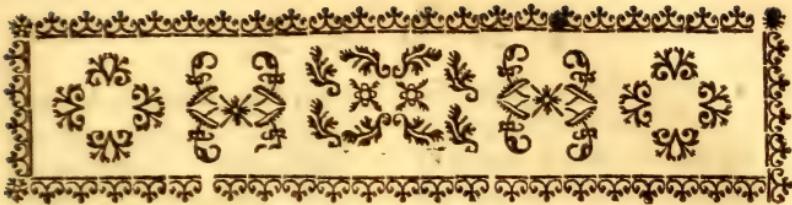
§ Boyle on the wholesomeness of the air.

part-

§§ Leopoldi relatio de itinere suecico, p. 81.

** De triplici philosophia, p. 202.

part-water, to which put four loths of sal ammoniac, pour off the solution, suffer it to evaporate, and the *marcasita* remains at bottom. Take of this marcasite twelve loths, gold-calx, or leaf-gold, two loths; sal ammoniac, and mercury sublimate, of each two loths; pure running quicksilver, sixteen loths; mix all together, and sublime for seven times, or so often, till at length all come to remain fixed at the bottom, and each time the sublimate is again to be mixed with what remains to bottom: mix this with two loths of sal-ammoniac, and imbibe it with one pound and a half of the alcali, to be described below, and the whole will turn to an oil. Give a gentle fire in the furnace called Piger-Henricus, with coals, or with the lamp, for a month, and it will become dry (*congelabitur.*) Of this medicine take two loths to ten pounds of well purified quicksilver, give a gradual fire in a wind-furnace, and let it stand for an hour in flux, and it will be fixed to a gold, and tinge copper and silver. The alcali for the purpose is thus prepared. Pour vinegar on alcali, 'till it come to clot, or bear being made into balls, and let it dry in the sun, then give a reverberating fire for twenty four hours; rub it fine, and dissolve it in twice its quantity of distilled vinegar; distil, cohobate with the very same vinegar; distill once more, and let it run, *per deliquium*, in a moist place, on a marble or glass; dry it again, and again run it, the process is to be frequently repeated; and, what is surprising! it reduces all spirits and bodies (*spiritus et corpora*) to a water, and is a highly valuable secret.—Let who will try it for me, I cannot.



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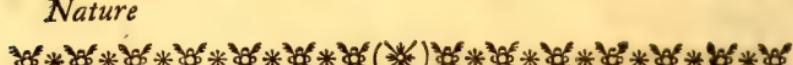
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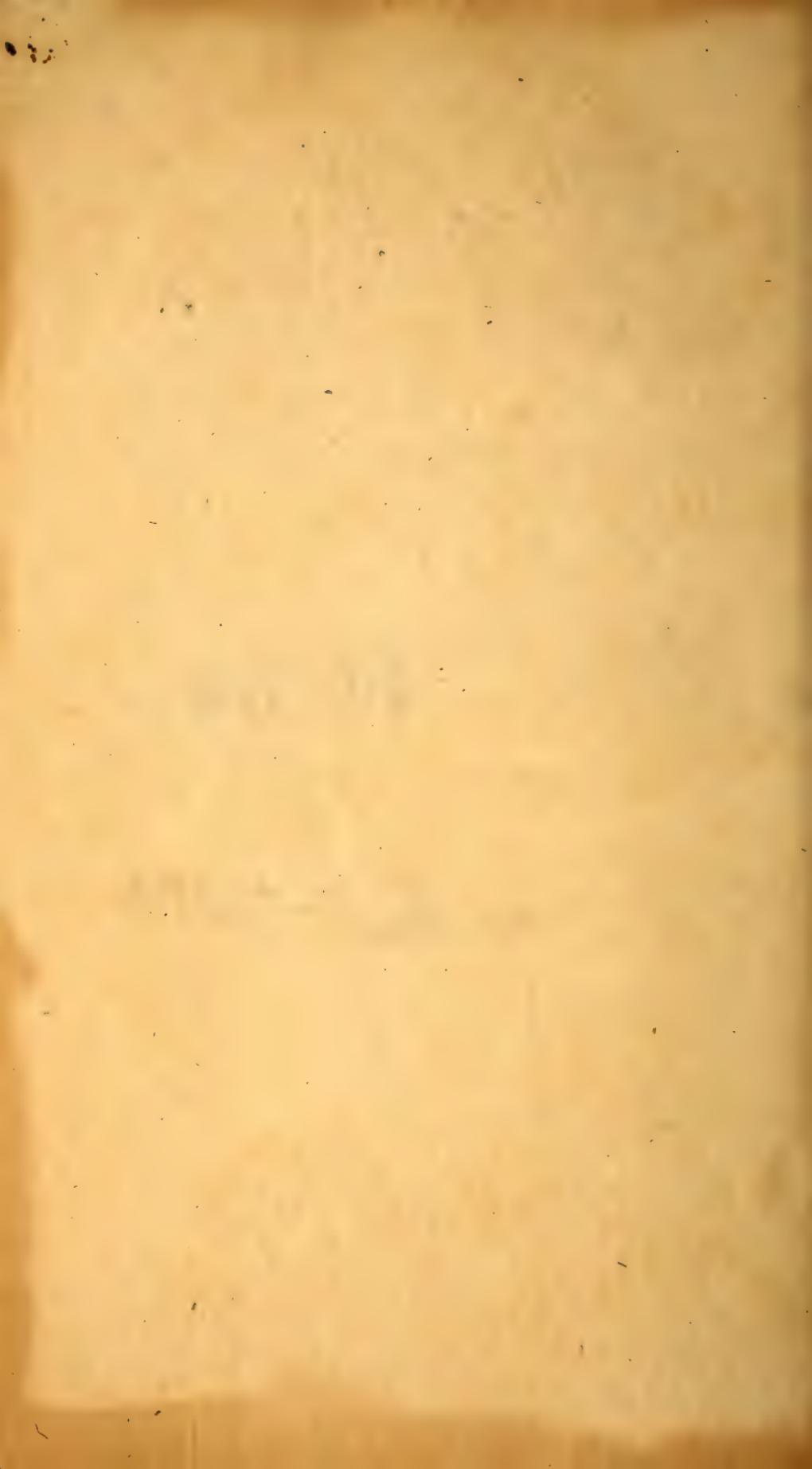
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